Screening For Environmental Concerns At Sites With Contaminated Soil and Groundwater

Volume 2: Background Documentation For The Development of Tier 1 Environmental Screening Levels

Prepared by:

California Regional Water Quality Control Board
San Francisco Bay
1515 Clay Street, Suite 1400
Oakland, California 94612

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Contact:
Roger C. Brewer, Ph.D.
Associate Engineering Geologist
Telephone: 1-510-622-2374
E-mail: rbrewer@waterboards.ca.gov

                     OR

Stephen Hill, Chief
Toxics Cleanup Division
Telephone: 1-510-622-2361
E-mail: shill@waterboards.ca.gov

California Regional Water Quality Control Board
San Francisco Bay
1515 Clay Street, Suite 1400
Oakland, California 94612

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VOLUME 2: BACKGROUND DOCUMENTATION FOR THE DEVELOPMENT OF TIER 1 SOIL AND GROUNDWATER SCREENING LEVELS

APPENDICES

GLOSSARY OF TERMS

AWQC: Aquatic Water Quality Criteria
CCC: Criterion for Continuous Concentration
CCM: Criterion for Maximum Concentration
CTR: California Toxics Rule
DHS Department of Health Services
EPA: Environmental Protection Agency
ESL: Environmental Screening Level (formerly "RBSL")
FVC: Final Chronic Value
HH: Human Health-consumption of aquatic organisms
LOEL: Lowest-Observed-Effects Level
MADEP: Massachusetts Department of Environmental Protection
MCL: Maximum Concentration Level
MOEE: Ontario Ministry of Environment and Energy
MTBE: Methyl tert-Butyl Ethylene
PCE: Tetrachloroethylene
PRG: Preliminary Remediation Goals
RBSL: Risk-Based Screening Level
RWQCB: Regional Water Quality Control Board
TPH: Total Petroleum Hydrocarbons
USEPA: U.S. Environmental Protection Agency
USDOE: U.S. Department of Energy

APPENDIX 1

DEVELOPMENT OF TIER 1 LOOKUP TABLES

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DEVELOPMENT OF TIER 1 LOOKUP TABLES

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Development of Tier 1 Lookup Tables

1.1 Introduction

Compilation and presentation of the environmental screening levels (ESLs) presented in this document is modeled after similar documents published by the Ontario Ministry of Environment and Energy (MOEE 1996), the Massachusetts Department of Environmental Protection (MADEP 1994) and the Netherlands (Vetger 1993). Screening levels for the following environmental concerns are presented (refer also to Figure 1):

Groundwater:
- Protection of human health
    - Current or potential drinking water resource;
    - Emission of subsurface vapors to building interiors;
- Protection of aquatic habitats (discharges to surface water);
- Protection against nuisance concerns (odors, etc.) and general resource degradation.

Soil:
- Protection of human health
    - Direct/indirect exposure with impacted soil (ingestion, dermal absorption, inhalation of vapors and dust in outdoor air);
    - Emission of subsurface vapors to building interiors;
- Protection of groundwater quality (leaching of chemicals from soil);
- Protection of terrestrial (nonhuman) habitats;
- Protection against nuisance concerns (odors, etc.) and general resource degradation.

Shallow Soil Gas:
- Protection of human health
    - Emission of subsurface vapors to building interiors.

For use in this document, the term "soil" refers to any unconsolidated material found in the subsurface, including actual soil, saprolite, sediment, fill material, etc. Screening levels for each concern are organized as follows:

¹BENEFICIAL USE OF THREATENED GROUNDWATER	²LOCATION OF IMPACTED SOIL	
	Shallow Soil (≤ 3m bgs)	³Deep Soil (> 3m bgs)
Current or Potential Source of Drinking Water	Soil: Tables A-1, A-2 Soil Gas: Table E-3 Water: Table F-1	Soil: Tables C-1, C-2 Water: Table F-1
NOT a Current or Potential Source of Drinking Water	Soil: Tables B-1, B-2 Soil Gas: Table E-3 Water: Table F-2	Soil: Tables D-1, D-2 Water: Table F-2

bgs: below ground surface
1. Shallow-most saturated zone beneath the subject site and deeper zones as appropriate.
2. Depth to top of impacted soil from ground surface (3 meters = 10 feet).
3. Application of Deep Soil ESLs to soils <3m deep may require institutional controls (see text).

The A through D series tables summarize individual screening levels complied for soil under unrestricted (A-1, B-1, C-1, D-1) and commercial/industrial (A-2, B-2, C-2, D-2) land use scenarios. The Table E series summarizes screening levels complied specifically for indoor-air impact concerns. Screening levels for groundwater and surface water are summarized in the Table F series. Tables G through L provide supporting screening levels and other information for the earlier tables.

A discussion of screening levels compiled for surface water and groundwater is provided in Chapter 2. A detailed discussion of screening levels compiled for soil is provided in Chapter 3. Chapter 4 discusses screening levels compiled for indoor air and related screening levels for shallow soil gas. Screening levels developed for Total Petroleum Hydrocarbon (TPH) are discussed in Chapter 5. Other issues pertinent to the lookup tables are discussed in Chapter 6.

1.2 Example Selection of Tier 1 ESLs for Tetrachloroethylene (PCE)

Figure 2 illustrates the selection of final Tier 1 soil and groundwater ESLs for the chemical tetrachloroethylene (PCE). The example assumes impacts to shallow soils (≤3 meters below ground surface) under an unrestricted (e.g., residential) land-use scenario. Groundwater immediately underlying the site is assumed to be a potential source of drinking water. This scenario places the site under Table A-1 of the Tier 1 lookup tables (refer to Section 1.1).

The Tier 1 ESL for PCE in shallow soil is selected as the lowest of the individual screening levels for Direct Exposure (0.48 mg/kg), Indoor-Air Impacts (0.09 mg/kg), Terrestrial Biota concerns (60 mg/kg), Ceiling Level (370 mg/kg) and Groundwater

Protection (leaching concerns, (0.70 mg/kg)). The final soil ESL for PCE is the lowest of the individual screening levels, or 0.09 mg/kg.

The process for selection of a Tier 1 PCE ESL in groundwater is similar (refer to Figure 2). Individual screening levels for Drinking Water (5.0 ug/L), Indoor Air (130 ug/L), Discharge to Surface Water (120 ug/L) and Ceiling Level (170 ug/L) concerns are compared and the lowest of these is selected for inclusion in the Tier 1 lookup tables. In this example, the groundwater screening level for drinking water concerns drives potential risks and is selected as the Tier 1 ESL (5.0 ug/L). Note that two screening levels are presented in the lookup tables for indoor air concerns (Table E-1b), one for high-permeability vadose-zone soils (120 ug/L) and one for low-permeability soils (500 ug/L). Only the screening level for sites with high-permeability vadose-zone soils is carried through for inclusion in the summary lookup tables, however (refer to Tables F-1 and F-2).

Selection of ESLs for PCE in deep soils is similar. For deep soils, however, potential impacts to terrestrial biota are not considered, the direct-exposure screening level is modified to reflect a less stringent, construction/trench worker exposure scenario, and the ceiling level is generally somewhat less stringent. Screening levels for groundwater protection concerns remain the same.

The process described above was carried out for each of the 100+ chemicals included in the Tier 1 lookup tables under each combination of groundwater beneficial use, soil depth and land use. The results are summarized in Tables A through D (soil) and Table F (groundwater) of this appendix. As can be seen from a review of these tables, the selection of final, Tier 1 ESLs for highly mobile or highly toxic chemicals is typically driven by groundwater protection or indoor-air impact concerns (e.g., see selection process for benzene or vinyl chloride ESLs in Table A-1). Final ESLs for chemicals that are relatively immobile in soils but highly toxic are typically driven by direct-exposure concerns (e.g., see selection process for PCBs in Table A-1). In contrast, selection of ESLs for heavy metals that are relatively non-toxic to humans is typically driven by ecological concerns or ceiling levels for general resource degradation (e.g., see selection process for copper ESL in Table A-1). For chemicals that have particularly strong odors, selection of ESLs may be driven in part by nuisance concerns or "ceiling levels" (e.g., see Total Petroleum Hydrocarbons (TPH) in Table B-1). The consideration of ceiling levels becomes especially important in the selection of ESLs for relatively immobile chemicals in isolated, deep soils (e.g., refer to Table C-1).

1.3 Cumulative Risk

Additive risk due to the potential presence of multiple chemicals with similar target health effects is addressed under Tier 1 through use of conservative exposure assumptions (exposure frequency and duration, ingestion and inhalation rates, etc.) and target risk levels. Exposure assumptions used to develop direct-exposure and indoor-air

screening levels are primarily based on parameter values presented in USEPA risk assessment guidance for Superfund sites (refer to USEPA 2004). Alternative, and in some cases less conservative, exposure assumptions are presented in the USEPA technical document *Exposure Factors Handbook* (USEPA 1997), among other examples. For example, recommended inhalation rates for residents are 11.3 m3/day for women and 15.2 m^3/day for men, in comparison to the value of 20 m^3/day used to develop the direct-exposure screening levels presented in this appendix (Section 3.2). The average time (50th percentile) spent at one residence is also stated to be 9.0 years, in contrast to the more conservative exposure duration used of 30 years. The average occupational tenure is similarly stated to be 6.6 years, in contrast to the occupational exposure duration used of 25 years. While the more conservative exposure assumptions are still generally recommended for use in site-specific risk assessments, the variance in the assumptions helps to demonstrate the overall conservative nature of the models referenced in this document.

For carcinogens, the human health screening levels presented are based on a target excess cancer risk of 10^{-6}. This represents the upper end (most stringent) of the potentially acceptable range of 10^{-4} to 10^{-6} recommended by the USEPA (USEPA 1989a,b). As stated in the National Contingency Plan, however, "The 10^{-6} level shall be used as the point of departure for determining remediation goals..." (USEPA 1994). Remediation or risk management is rarely warranted at sites where the estimated cancer risk does not exceed 10^{-6}. Remediation or risk management is almost always warranted at sites where the estimated cancer risk exceeds 10^{-4}. For sites where the estimated risk is between 10^{-4} and 10^{-6}, the need for active remediation or risk management is evaluated on a site-specific basis (i.e., risks within this range are "potentially acceptable", depending on site-specific considerations).

The use of alternative exposure assumptions in a more "detailed" risk assessment could result in an increase of direct-exposure screening levels by a factor of three or more while still meeting a target excess cancer risk of 10^{-6}. Based on above discussion and the conservative nature of the human exposure models in general, the direct-exposure screening levels presented in this appendix and the soil ESLs in general are considered to be adequate for use at sites where up to three carcinogenic chemicals of concern have been identified. Additional evaluation may be required for sites where more than three carcinogens are identified.

A cumulative, target Hazard Index of 1.0 is typically used in human health risk assessments for evaluation of noncarcinogenic risks. The USEPA Preliminary Remediation Goals (PRGs) for soil were developed based on a chemical-specific, target Hazard Quotient of 1.0. To account for potential cumulative effects, the PRGs were adjusted to a target Hazard Quotient of 0.2 for use in the ESL lookup tables (see Section 3.2 and Tables K-1 and K-2). This adjustment reflects an assumption that up to five chemicals with the same chronic health effects may be present at a given site. A similar target Hazard Quotient was used by the Massachusetts DEP (MADEP 1994) and Ontario MOEE (MOEE 1996) to develop screening levels for direct-exposure concerns.

Additional evaluation may be required for sites where more than five chemicals with similar noncarcinogenic health effects are present. For reference, a compilation of chronic health effects for the chemicals listed in the ESLs is provided in Table L of this appendix.

As one exception, a Hazard Quotient of 0.5 was used for calculation of health-based screening levels for Total Petroleum Hydrocarbons (TPH, see Appendix 2). The parameter TPH incorporates a multiple of chemicals within specified carbon ranges. In effect, this partially addresses potential cumulative risk concerns and a less stringent target Hazard Quotient is considered justified. The need to calculate cumulative risks in more detail should be evaluated on a site-by-site basis.

The direct-exposure screening levels not address potential synergistic effects (e.g., 1+1=3). Synergistic effects are primarily of concern for exposure to multiple chemicals at concentrations significantly higher than those expressed in the direct-exposure ESLs. Conservative target risk goals (e.g., target excess cancer risk of 10^{-6}) and exposure parameters used to develop the screening levels further reduce this concern. Methods to quantitatively assess synergistic effects have not been developed.

2

Groundwater And Surface Water Screening Levels

2.1 Introduction

Screening levels for groundwater and surface water are summarized in the "F" series of tables at the end of this appendix. A discuss of individual concerns considered in the screening levels is provided in this Chapter and summarized below. For the purpose of developing Tier 1 screening levels, it is assumed that all groundwater could at some point in time potentially discharge to a body of surface water. Discharge could occur through natural processes (e.g., natural discharge of groundwater to a stream, river, lake, wetland, bay, etc. via springs) or through human activities (e.g., pumping and discharge of groundwater at remediation or construction dewatering projects).

The final groundwater ESL for sites that threaten drinking water resources reflects the lowest of a chemicals screening level for drinking water toxicity, aquatic habitat protection (discharges to surface water), indoor-air impacts (volatile chemicals only) and a "ceiling level" for tastes & odors or other nuisance concerns (Table F-1a). The final groundwater ESL for sites that do not threaten drinking water resources (Table F-1b) reflects the lowest of a chemicals screening level for the same set of environmental concerns with the exception of the drinking water component and an alternative ceiling level.

Screening levels for surface water were compiled in a similar manner with the exception that impacts to indoor air were not considered. For freshwater surface water bodies, the final ESL reflects the lowest of a chemicals screening level for drinking water toxicity, aquatic habitat protection (discharges to surface water) and nuisance concerns (Table F-2a). For marine surface water bodies, the final ESL reflects the lowest of a chemicals screening level for aquatic habitat protection (discharges to surface water) and nuisance concerns (Table F-2b). For estuarine systems, the lowest of the screening levels for freshwater and marine surface water bodies were selected (Table F-2c).

As discussed below, groundwater screening levels for potential discharges to aquatic habitats only consider goals for chronic surface water quality goals. Aquatic habitat goals for surface water consider an additional goal/standard for the potential bioaccumulation of contaminants in aquatic organisms and subsequent consumption of the organisms by humans. Use of the bioaccumulation goals as additional screening levels for groundwater should be evaluated on a site-by-site basis.

2.2 Screening Levels for Drinking Water (Toxicity)

A summary of drinking water standards and guidelines used in this document is provided in Table F-3. The Central Valley Water Board technical document *A Compilation of Water Quality Goals* (RWQCBCV 2000 and updates) was used as the primary reference. Screening levels for drinking water intended to address human toxicity were generally selected based on the following order of preference:

- California DHS Primary Maximum Contaminant Level (MCL);

- CalEPA OEHHA Public Health Goal;

- California DHS Action Level based on toxicity;

- Risk-based goal calculated using California DHS model.

(Note that the above order of preference may differ in other regions of California.)

California or USEPA primary MCLs for drinking water are available for most chemicals listed in the lookup tables. Although numerous factors are taken into account in development of primary MCLs (toxicity, detection limits, attainability, etc.), these standards are primarily intended to address toxicity to humans in drinking water supplies and are used for this purpose in this document.

For chemicals where Primary MCLs have not been promulgated, toxicity-based Public Health Goals (PHGs) published by the California Office of Environmental Health Hazard Assessment (OEHHA) were referred to. If a PHG was not available, toxicity-based Action Levels published by the California Department of Health Services (CalDHS) were used. In cases where MCLs, PHGs of Action Levels were not available, separate risk-based goals were calculated using the CalDHS model as presented in the Central Valley Water Board technical document referenced above (equations also presented in Appendix 2 of this document). Risk-based goals for noncarcinogenic effects take precedence over goals for carcinogenic effects if lower. Drinking water goals intended to address taste and odor concerns (e.g., Secondary MCLs) take precedence over toxicity-based goals if lower (discussed under ceiling levels for groundwater, Section 2.5).

For comparison purposes, tapwater "Preliminary Remediation Goals" prepared by USEPA Region IX are presented in Table F-6. Goals for carcinogens were adjusted to CalEPA cancer potency factors when available. For volatile chemicals, the tapwater

goals take into account uptake via inhalation of vapors during showering and other activities in addition to toxicity via normal ingestion of drinking water. Goals for nonvolatile chemicals are based on ingestion only. Equations for the USEPA Region IX tapwater goals are included in Appendix 2.

2.3 Screening Levels for Aquatic Habitat Protection

2.3.1 Surface Water Aquatic Habitat Goals

A summary of aquatic habitat goals considered for use in this document is provided in Tables F-4a through F-4d. Separate goals were compiled for freshwater, marine and estuarine habitats. Locally, the areas south of the Dumbarton Bridge and east of the Richmond-San Rafael Bridge to the upstream extent of tidal influences are considered to be estuarine. Tidally influenced portions of creeks, rivers and streams flowing into the Bay between these areas should also be considered to be estuarine in screening level assessments. Final goals were selected based on the following order of preference and availability:

- CTR CCC;

- USEPA CCC;

- Lowest of USEPA Ecotox AWQC and FVC Threshold Value (or Tier II value if no AWQC or FVC) or 50% USEPA Chronic LOEL;

- USDOE Chronic PRG;

- 50% MOEE Chronic AWQC or LOEL;

- 10% CTR CMC

- 10% USEPA CMC (or 10% Acute LOEL if no CMC);

- 10% MOEE Acute AWQC or LOEL;

- Other aquatic water quality criteria (e.g., 5% LC 50);

- Drinking water screening level.

abbreviations:
AWQC: Aquatic Water Quality Criteria
CCC: Criterion for Continuous Concentration
CCM: Criterion for Maximum Concentration
CTR: California Toxics Rule (as presented in RWQCBCV 2000 and USEPA 2000)
EPA: Environmental Protection Agency
FVC: Final Chronic Value
LC50: Lethal Concentration (50th percentile)
MOEE: Ontario Ministry of Environment and Energy

PRG: Preliminary Remediation Goals
USEPA: U.S. Environmental Protection Agency
USDOE: U.S. Department of Energy (chronic values only)

Goals provided in each reference are generally based on dissolved-phase concentrations of the chemicals in water. Goals for arsenic, selenium and chromium VI are, however, based on total concentrations.

Chronic freshwater goals were used as screening levels for saltwater ("marine") if chronic goals for the latter were not available, and vise versa. Acute goals were substituted in a similar manner. Other exceptions to the prioritization scheme include the use of chemical-specific USDOE PRGs in place of USEPA chronic LOELs when the LOEL was developed for a general group of compounds rather than a specific chemical (e.g., halomethanes). In addition, surface water goals for mercury are based on the San Francisco Bay Basin Water Quality Control Plan (Basin Plan, RWQCBSF 1995). Surface water goals for selenium are based on the National Toxics Rule (USEPA 1992).

The primary sources of data for chronic and acute surface water criteria specific to California were the *Region 2 Basin Plan* (RWQCBSF 1995), the California Toxics Rule as promulgated in *40 CFR Part 131: Water Quality Standards, Establishment of Numerical Criteria for Priority Toxic Pollutants for the State of California* (USEPA 2000) and the California EPA technical document *A Compilation of Water Quality Goals* (RWQCBCV 2000). Other sources referenced to include the following: USEPA's *Ecotox Thresholds* (USEPA 1996b), USEPA's *National Recommended Water Quality Criteria* (USEPA 2002), U.S. Department of Energy's *Preliminary Remediation Goals for Ecological Endpoints* (USDOE 1997), and Ontario MOEE's Rational For The Development and Application of Generic Soil, Groundwater and Sediment Criteria (MOEE 1996). (Note that the US Fish and Wildlife Service issues on opinion that the CTR standards for selenium, mercury, PCP and cadmium may not be protective of some endangered and threatened species (USFWS 2000). Responsible parties for sites where surface water is or could be impacted by these chemicals should review updated goals for these chemicals as available.)

For chemicals where chronic, No Adverse Effect Level goals or the equivalent were not available, alternative goals were selected and modified as noted (refer also to Table F-4a). Modification factors in general followed recommendations and methods provided in the USEPA Great Lakes water quality initiative guidance (USEPA 1995).

Surface water standards for potential bioaccumulation of chemicals in aquatic organisms and subsequent human consumption of these organisms are presented in Table F-4d. Both California and Federal standards are given.

2.3.2 Groundwater Screening Levels for Aquatic Habitat Impacts

For the purposes of this document, and based on the natural setting of the San Francisco Bay area, it is assumed that groundwater could discharge into an estuary environment. As such, goals for aquatic habitat protection are based on the lowest of the goals for marine versus freshwater environments. For settings where this is not appropriate, target surface water goals and correlative groundwater goals can be adjusted on a site-specific basis.

Dilution of groundwater upon discharge to surface water was not considered in the selection of groundwater screening levels for aquatic habitat protection. Benthic organisms were assumed to be exposed to the full concentration of chemicals in impacted groundwater prior to mixing of the groundwater with surface water. Potential dilution of groundwater upon discharge to surface water or in groundwater "mixing zones" adjacent to shorelines areas was therefore not appropriate for development of conservative screening levels. Adjustment of the final groundwater screening levels with respect to potential dilution may, however, be appropriate on a site-specific basis (e.g., no significant benthic habitat present, see Volume 1, Section 3.0).

The USEPA Ecotox goal for barium (3.9 ug/L) was not considered as a screening level for groundwater due to low confidence in the goal and comparison to reported natural background concentrations of this metal in Bay area groundwater (up to >100 ug/L). Background concentrations of boron, copper, lead, mercury, selenium, thallium and zinc have also been reported in excess of the groundwater screening levels presented in Tables F-1 and F-2. This issue is being further evaluated by the RWQCB.

Surface water standards for potential bioaccumulation of chemicals in aquatic organisms and subsequent human consumption of these organisms were not considered in the selection of groundwater screening levels for potential aquatic habitat impacts. Use of these standards would be excessively conservative at the large number of relatively small sites overseen by the RWQCB. Consideration of the standards may be appropriate for sites where the discharge of large plumes of impacted groundwater threatens long-term impacts to important aquatic habitats. This should be evaluated on a site-by-site basis.

2.4 Groundwater Screening Levels for Potential Vapor Intrusion Concerns

2.4.1 Vapor Intrusion Model Parameters

Groundwater screening levels intended to address the intrusion of vapors into buildings and subsequent impact on indoor-air quality are summarized in Table E-1a and included in Tables F-1 and F-2. Correlative soil gas screening levels and indoor air screening levels are presented in Tables E-2 and E-3, respectively, and discussed in Chapter 4.

The screening levels were generated using a computer spreadsheet model published by the U.S Environmental Protection Agency (available online, USEPA 2003a). The spreadsheet is based on a model presented in the document *Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors Into Buildings* (Johnson and Ettinger, 1991). The model considers both diffusive and convective flow of subsurface vapors into buildings. Summary text from the guidance document accompanying the spreadsheet is provided in Appendix 3, as is a sensitivity evaluation of the Johnson and Ettinger model. Example printouts of the model as used to calculate screening levels for this document are included in Appendix 4. Input parameter values used in the models are noted in the examples (front pages). Default parameters values presented in the spreadsheet technical document were generally selected for use.

Human exposure assumptions were set equal to assumptions used in the USEPA Region IX PRGs. Default, USEPA toxicity factors included in the original spreadsheet were replaced with California EPA factors as available (see Appendix 4, last page of first example). As done in the soil direct-exposure models, screening levels were calculated using a target risk of $1x10^{-6}$ for chemicals with carcinogenic health effects and a target hazard quotient of 0.2 for chemicals with noncarcinogenic health effects (0.5 for TPH). For consistency purposes, default physio-chemical constants included in the spreadsheet were replaced with constants used in the USEPA PRGs models if different.

All groundwater was assumed to potentially flow offsite and pass under residential areas. Final screening levels are therefore based on a residential land use exposure scenario. Groundwater screening levels for commercial/industrial areas are included in Table E-1a for reference but were not carried on for use in subsequent lookup tables.

Default building characteristics presented in the spreadsheet guidance were used in the models. The thickness of the building floor was assumed to be 15 cm. For both residential land use and commercial/industrial exposure scenarios, the models assume a small (9.6m x 9.6m square), one-story building situated on mono-slab concrete base. This may be overly conservative for commercial/industrial sites with existing, larger buildings but is considered to be protective of future redevelopment of such sites. A default value of 1mm was used for the assumed perimeter crack width. For screening level evaluation of larger buildings, an assumed crack spacing of 10m is recommended. A default ceiling height of 2.44 meters was retained for use in the ESL models.

The model also assumes that potential convective flow from the subsurface into buildings (i.e., flow driven by air pressures that are lower inside the building than in the vadose zone) is not short circuited by open crawl spaces or other building designs that negate differences between indoor and subsurface air pressures. Default indoor-air exchange rates of one-time per hour for residences and two-times per hour for commercial/industrial buildings are based on a comparison of risk assessment guidance published by the City of Oakland (Oakland 2000) and comments received during a 2003 peer review of the December 2001 edition of the screening levels document (RWQCBSF 2003).

The vapor intrusion model is highly sensitive to the permeability of vadose-zone soil that soil gas must migrate through before being emitted at the ground surface. Screening levels generated for sites characterized by fine-grained, vadose-zone soils (clays and silts) of low permeability can be several orders of magnitude less stringent (i.e., higher) than those calculated for more permeable, coarse-grained soils. For this reason, screening levels were developed for both soil types. In Table E-1a, the first screening level presented is intended for use at sites with vadose-zone soils of highly to moderately permeability. The second screening level is intended for use at sites with lower permeability soils in the vadose zone.

For the purposes of this document, the high-permeability vadose-zone soil profile is modeled as one meter of coarse-grained, dry, sandy soil (S) overlying two meters of somewhat more moist clayey loam (CL, 1/3 sand, 1/3 silt, 1/3 clay). This is considered to be representative of the majority of sites in the Bay area. The low permeability soil profile is modeled as one meter of loamy sand loam (LS) overlying two meters of silt (SI). "Sand" is defined as material that is equal to or greater than 0.075 mm in diameter (i.e., will not pass through a U.S. Standard 200 mesh sieve). Silt and clay are defined as material that is less than 0.075 mm in diameter (i.e., will pass through a U.S. Standard 200 mesh sieve). These definitions are consistent with default parameter values for soil types presented in the USEPA model (USEPA 2003a). The depth to from the ground surface to the top of impacted groundwater in both sets of models was assumed to be 3.0 meters. This is just above the minimum thickness allowed for modeling of vapor transport through the low/moderate permeability vadose-zone soil profile due to capillary fringe height constraints.

Input soil parameter values for total porosity, water-filled porosity and fraction organic carbon for the upper portion of the soil profiles were set equal to values used by USEPA Region IX in development of the PRGs (USEPA 2004). Soil moisture was assumed to be somewhat higher for the lower soil units than the upper units, at 0.30 (vs 0.15), consistent with the default recommended in the USEPA vapor intrusion guidance document. Default values presented in the spreadsheet were used for remaining soil properties. For site-specific assessments, soil moisture data should be collected within five feet of the groundwater surface and well above the capillary fringe zone.

Default soil vapor permeability values for the selected soil types were used in the models. For site-specific estimation of this parameter, the use of rigorous, in-situ methods intended for the design of soil vapor extraction systems is recommended. Secondary porosity and permeability in fine-grained soils can be significantly enhanced by plant roots, desiccation cracks, disturbance during redevelopment, faulting, etc. Reliance on a small number of borings or laboratory analysis could significantly underestimate the actual vapor permeability of the site and in turn underestimate the risk of potential impacts to indoor air.

Note that when using the spreadsheet to back calculate a groundwater screening level from an input target risk, the values appearing in the spreadsheet for "Csource"

(concentration in soil gas) and "Cbuilding" (concentration in indoor air) are based on a theoretical initial soil concentration of 1E-06 g/g or 1,000 micrograms per kilogram and are not directly related to the modeled screening level. The values presented do not represent actual modeled concentrations and should be ignored.

2.4.2 Background and Use of USEPA Vapor Intrusion Model

2.4.2.1 Background

The Johnson and Ettinger model incorporated into the USEPA vapor intrusion spreadsheets was originally developed to predict impacts to indoor air due to the subsurface emission of naturally occurring radon gas (Johnson and Ettinger, 1991). Pertinent sections of the guidance document published with the model are presented in Appendix 4. Based on concerns over the conservativeness of the model and a lack of field validation studies, the USEPA initially declined to promote use of the model to develop generic screening levels (USEPA 1996a, 2001). They instead suggested that the model should be used in conjunction with soil gas data to evaluate potential indoor air impacts. In 1997, however, the USEPA published a user's guide to the Johnson and Ettinger model and included a spreadsheet. The 2003 updates to the vapor intrusion spreadsheets developed by USEPA allowed direct input of soil gas data (USEPA 2003a).

The USEPA version of the Johnson and Ettinger considers both diffusive and convective flow of soil gas into buildings. Diffusive flow occurs as soil gas migrates from areas of higher concentration to areas of lower concentration. Wind effects and indoor heating can cause a decrease in air pressure inside a building and lead to upward, convective flow of subsurface vapors through cracks and gaps in the building floor. As described in the USEPA guidance document, effective convective flow of subsurface vapors into buildings is expected to be limited to deep soils within the "immediate" area of the building.

2.4.2.2 Adjustment of Screening Levels

Field studies at sites impacted by volatile chemicals have clearly documented impacts to indoor air due to the intrusion of subsurface vapors, particularly for sites where soil or groundwater has been impacted by chlorinated volatile organic compounds. One example is the report *An Evaluation of Vapor Intrusion Into Buildings Through A Study of Field Data* prepared by staff of the Massachusetts DEP (Fitzpatrick and Fitzgerald 1997). Results of the Massachusetts DEP study suggest that the vapor intrusion model may over-predict the concentration of chlorinated, volatile chemicals in soil gas by an order of magnitude or more with respect to the measured concentration of the chemical in groundwater, although in some cases the model appeared to be slightly under conservative. More significantly, the Massachusetts DEP field study indicated that the vapor intrusion model over-predicted the soil gas concentration of petroleum-based volatile organic compounds (e.g., benzene) in the vadose zone by up to three or more orders of magnitude. This was interpreted to reflect substantial, natural biodegradation of

the vapor-phase of these chemicals in the subsurface. This in turn causes the models to over predict impacts to indoor air by several orders of magnitude and makes use of the model for this group of chemicals questionable, particularly in the absence of field-based soil gas data.

To account for the potentially over conservative nature of the vapor intrusion model for nonchlorinated volatile chemicals, screening levels generated by the model were adjusted upwards by a factor of ten (refer to Table E-1a). As discussed below, the use of soil gas data in combination with groundwater studies may be most appropriate for evaluating sites where a more detailed evaluation of this issue is warranted. Evaluation of this issue is ongoing.

2.5 Surface Water and Groundwater Ceiling Levels For Gross Contamination Concerns

Ceiling levels based on gross contamination concerns for surface water and groundwater are summarized in the Table I series. Ceiling levels for surface water and groundwater that is considered to be a current or potential source of drinking water are based on the lowest of the chemicals taste and odor threshold (e.g., Secondary MCLs), one-half the solubility and a maximum of 50000 ug/L for any chemical based on general resource degradation concerns (Tables I-1 and I-3, after MADEP 1994). Taste and odor thresholds for drinking water were selected in the following order of preference and availability:

- California Department of Health Services (DHS) Secondary MCLs;

- USEPA Secondary MCLs;

- California DHS taste and Odor Action Levels;

- Taste and odor levels developed by Amoore and Hautala (as presented in RWQCBCV 2000);

- Odor thresholds presented in Massachusetts DEP (MADEP 1994) and Ontario MOEE (MOEE 1996) guidance documents.

With the exception of the MADEP and MOEE odor thresholds, data for each of the listed sources are summarized in the document *A Compilation of Water Quality Goals* (RWQCBCV 2000 and updates).

Ceiling levels for surface water and groundwater that is NOT considered to be a current or potential source of drinking water were selected in a similar manner with the exception that the drinking water taste and odor thresholds were replaced with general nuisance thresholds and gross contamination concerns (Tables I-2 and I-4). Nuisance thresholds are intended to reflect the concentration at which a chemical in water poses unacceptable odor problems. Thresholds presented in the Massachusetts DEP and Ontario MOEE

guidance documents were used as the primary sources of data. Taste and odor levels developed by Amoore and Hautala (in RWQCBCV 2000) were referred to for chemicals that lack odor thresholds in the Ontario guidance, although taste considerations for drinking water could cause these criteria to be overly stringent. It is apparent, however, that similar sources were used to develop both the Ontario MOEE and the Amoore and Hautala databases (compare Tables I-1 and I-2). In keeping with the Ontario and Massachusetts guidance documents, a ten-fold dilution/attenuation of chemical concentrations in groundwater upon discharge to surface water was assumed (non-drinking water resources, nuisance thresholds only). The nuisance threshold for MTBE presented in Table I-2 is based on average, upper range at which most subjects in a USEPA study could smell MTBE in water (180 ug/L), as summarized in the public health goals document for MTBE prepared by Cal EPA (CalEPA 1999a). This was selected as a nuisance screening level for MTBE in surface water. Assuming a dilution factor of ten yields the odor threshold of 1,800 ug/L for groundwater.

2.6   Other Groundwater Screening Levels

Additional screening levels for groundwater provided in the California EPA technical document *A Compilation of Water Quality Goals* include USEPA and National Academy of Sciences "Suggested No-Adverse-Response (SNARL)" goals for toxicity other than cancer risk and "Agricultural Water Quality" goals developed by the United Nations (RWQCBCV 2000). The SNARL goals largely duplicate risk-based screening levels for drinking water presented in Table F-3. Agricultural Water Quality goals for 12 metals are provided in Table F-5. These goals were not considered in the final lookup tables but may need to be considered on a site-specific basis. The agricultural goals are higher than screening levels for both drinking water and surface water protection for seven of the 12 metals listed. Agricultural goals for copper, cobalt, selenium and zinc are higher than goals for aquatic habitat protection but are lower than goals for drinking water (i.e., drinking water goals may not be adequately protective for irrigation use). The agricultural goal for molybdenum is lower than both the drinking water goal and the surface water goal for this metal. The development of these goals was not reviewed for preparation of the ESL document.

3

Soil Screening Levels

3.1   Introduction - Shallow Versus Deep Soils

Residents and commercial or industrial workers may regularly be exposed to contaminated, vadose-zone soils or dust derived from these soils (Regular exposure to contaminated soils below the water table is not generally considered except for construction workers.) A depth of three meters (approximately 10 feet) is used to delineate between shallow, "surface" soils where regular exposure to residents and/or workers is assumed and deeper, "subsurface" soils where only periodic contact during construction and utility maintenance work is assumed (refer also to Section 2.5 of Volume 1). A depth of three meters is consistent with guidance presented in the CalEPA document *Supplemental Guidance For Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (CalEPA 1996). This is regarded as the maximum, likely depth that impacted soil could at some point in the future be excavated and left exposed at the surface. The potential for deeper soils to be brought to the surface during large-scale redevelopment activities should be evaluated on a site-by-site basis.

Environmental concerns specifically considered for shallow versus deep soil ESLs are summarized in Table 3-1. For shallow soils, the final ESL represents the lowest of a chemicals screening level for ecotoxicity, human direct-exposure (residential and commercial/industrial land use), indoor-air impact, leaching and the chemicals maximum ceiling level (nuisance concerns etc.). For deep soils, the final ESL represents the lowest of a chemicals screening level for human direct-exposure (trench/construction worker exposure), indoor-air impact, leaching and an alternative ceiling level. Screening levels for terrestrial biota concerns are not considered for deep soils.

Final ESLs for relatively non-mobile chemicals are generally less stringent for deep soils in comparison to shallow soils (e.g., compare final ESLs for polychlorinated biphenyls in Tables A-1 and C-1). A few exceptions are noted in Section 3.2. For chemicals that are highly mobile in the subsurface and easily leached from soil or emitted as vapors to the ground surface, groundwater protection and indoor-air impact concerns usually drive risk regardless of the depth of the impacted soil (e.g., chlorinated solvents). Final shallow and

deep soil ESLs for these chemicals are therefore identical (e.g., compare benzene and vinyl chloride ESLs in Tables A-1 and C-1).

3.2 Soil Screening Levels for Direct-Exposure Concerns

3.2.1 Shallow Soils

Screening levels for human health/direct-exposure concerns for shallow soils are summarized in Tables K-1 (residential land use exposure scenario) and K-2 (commercial/industrial exposure scenario). The screening levels are based primarily on *Preliminary Remediation Goals* ("PRGs") developed by the U.S. Environmental Protection Agency Region IX (USEPA 2004). Equations used by USEPA Region IX to calculate the direct-exposure screening levels are presented in Appendix 2. The PRGs are intended to be protective of residents and workers who may be exposed to chemicals in shallow soils on regular basis via incidental ingestion, dermal absorption, and inhalation of vapors and particulate matter. The PRGs are calculated based on a target risk of $1x10^{-6}$ (one-in-a-million) for chemicals with carcinogenic health effects and a target Hazard Quotient of 1.0 for chemicals with noncarcinogenic health effects.

For use in this document, the USEPA PRGs for carcinogens were adjusted to reflect California EPA cancer potency factors where available (CalEPA 2004a, refer to Table J of this appendix). For consistency purposes, cancer slope factors and reference doses used by OEHHA to develop the California Human Health Screening Levels (CHHSLs) were adopted for use in this document (CalEPA 2004b and 2005; refer to Table J in this volume and Section1.3.1 in Volume 1). An exception was the recognition of updated, USEPA cancer slope factors for polychlorinated biphenyls (see Table J). A target excess cancer risk of 10^{-6} was retained.

Skin absorption factors presented in the CHHSLs document were used in preference over absorption factors presented in the USEPA PRG document, as available (see Table J). Dermal absorption of volatile organic chemicals is not considered in the USEPA document but is considered in the CHHSLs document. This resulted in relatively minor reductions of corresponding soil direct-exposure screening levels.

As discussed in Section 1.3, the CalEPA CHHSLs and/or USEPA PRGs for noncarcinogens were divided by a factor of five in order to take into account possible cumulative health effects at sites where multiple chemicals are present (see Tables K-1 and K-2). This reflects a target Hazard Quotient of 0.2 and assumes that up to five chemicals with the same chronic target health effects may be present. (A target Hazard Quotient of 0.5 was used to develop health-based screening levels for TPH.) Incorporating a more conservative target Hazard Quotient in the screening levels reduces the need to calculate site-specific Hazard Indices at sites with a small number of

chemicals of concern and relatively moderate levels of contamination. Screening levels based a target Hazard Quotient of 1.0 are presented in the tables for reference. California EPA has not developed alternative toxicity factors for noncarcinogens.

3.2.2 Deep Soils

Direct-exposure screening levels for deep soils are summarized in Table K-3 (construction/utility workers exposure scenario). Only construction workers and utility trench workers are assumed to come into periodic contact with contaminants in deep soils. Exposure assumptions selected for this scenario are based on guidance presented in the USEPA *Exposure Factor handbook* (USEPA 1997), trench-worker risk assessment guidance developed by the Massachusetts Department of Environmental Protection (MADEP 1994), general direct-exposure assumptions included in the USEPA Region IX PRG document, and professional judgment (see Appendix 2, Table 1). As done was done for shallow soils, screening levels were calculated using a target risk of $1x10^{-6}$ for chemicals with carcinogenic health effects and a target Hazard Quotient of 0.2 for chemicals with noncarcinogenic health effects (0.5 for TPH). A more detailed summary of exposure assumptions and selected parameter values is included in Appendix 2.

In general, direct-exposure soil screening levels generated for the residential land use exposure scenario are more stringent (lower) than screening levels developed for the commercial/industrial and construction/trench worker exposure scenarios. This is due to the increasingly shorter assumed exposure duration (years) and frequency (days per year) for the latter two scenarios and the assumption that children will not be regularly present under these scenarios (see Appendix 2). Exceptions include direct-exposure screening levels developed for barium, beryllium, chromium VI, cobalt and nickel under the construction/trench worker scenario. Screening levels for these chemicals are more stringent under the construction/trench worker exposure scenario than under the commercial/industrial exposure scenario (see Table K-2). For chromium VI and cobalt, the construction/trench worker screening levels are also lower than the residential land use screening levels (see Table K-1). This is due to the combined high oral and/or inhalation toxicity of these chemicals and the assumed higher soil ingestion rate and higher level of air-born dust under the construction/trench worker exposure scenario. As noted in Tables K-1 and K-2, commercial/industrial and residential land use direct-exposure screening levels for these chemicals were replaced with construction/trench worker screening levels for use in the lookup tables if less stringent.

3.2.3 Lead

Direct-exposure screening levels for lead of 150 mg/kg and 750 mg/kg are presented for residential land use (Tables A-1, B-1 and K-1) and commercial/industrial land use (Tables A-2, B-2 and K-2), respectively. The commercial screening level is also presented for deep soils (Tables C-1, C-2, D-1, D-2 and K-3). The residential screening level of 150 mg/kg is published in the Office of Environmental Health Hazard Evaluation

document *Human-Health-Based Screening Numbers Developed to Aid Estimation of Cleanup Costs for Contaminated Soil* (CalEPA 2004b) and was developed through use of the DTSC LeadSpread model. The screening levels are based on a target maximum allowable level of lead in blood of 10 ug/dl (using the 99th percentile value). Children are assumed to be exposed to the impacted soil seven days a week under the residential exposure scenario and are not assumed to be present under the commercial/industrial land use scenario. The model incorporates concurrent exposure to lead in air at an ambient concentration of 0.0028 ug/m^3 and in drinking water at a concentration of 15 ug/L (Primary MCL). The screening level also takes into account the potential uptake of lead in home-grown produce. Additional information is provided in the referenced document.

The Department of Toxic Substances Control (DTSC) schools unit has published a screening level for lead of 255 mg/kg, also based on use of the DTSC LeadSpread model (CalEPA 2001). This screening level is based on an identical residential exposure scenario as noted above with the exception that uptake of lead in homegrown produce is not considered. While this screening level may be appropriate for schools and even high-density housing areas, the more comprehensive OEHHA screening level was selected for use at a screening level. USEPA Region IX presents a residential screening level for lead of 400 mg/kg (USEPA 2004). This screening level is based on a model similar to LeadSpread but only considers the uptake of lead via direct exposure to contaminated soil.

The commercial/industrial soil screening level for lead of 750 mg/kg referenced in Tables K-2 and K-3 of this document is based on the USEPA Region IX Preliminary Remediation Goal for this exposure scenario (USEPA 2004). The OEHHA CHHSLs document presents a lead screening level of 3,500 mg/kg for commercial/industrial exposure, based again on the DTSC LeadSpread model. While perhaps technically appropriate, this screening level may be excessively high for sites adjacent to residential areas that are susceptible to wind-blown dust from commercial/industrial areas. Residential exposure could occur via inhalation of air-born dust as well as ingestion of dust that has entered living spaces. A decision was therefore made to refer to the USEPA screening level.

As also stated in the OEHHA CHHSLs document, the commercial/industrial screening number of 3,500 mg/kg is above the hazardous waste, Total Threshold Limit Concentration for lead of 1,000 mg/kg (Title 22 of the California Code of Regulations). Because of the regulatory implications during remediation of a site, the document recommends that the actual screening level used be below 1,000 mg/kg (footnote to Table 5 in the updated OEHHA CHHSLs document). Use of the USEPA screening level satisfies this recommendation.

3.2.4 Background Metal Concentrations

Ambient background concentrations of arsenic in Bay area soils typically exceed risk-based screening levels for direct-exposure concerns. For example, the risk-based

screening level for arsenic in residential soils is 0.39 mg/kg (refer to Table K-1). The Lawrence Berkeley National Laboratory report *Background Distributions of Metals in the Soil at LBNL* (LBNL, 2002) presents a range of mean concentrations of arsenic in soil samples from the property of 0.30 mg/kg to 42 mg/kg, however, with an arithmetic mean of 5.5 mg/kg. Soils tested at the site span a range of geologic environments. Based on an informal review of environmental reports submitted to the RWQCB, a range of 5 mg/kg to 20 mg/kg is typical for much of the Bay area. Concentrations of arsenic in soil tend to be higher in soils associated with silicic volcanic rocks and hydrothermally altered rocks.

As a provisional measure, the mean concentration of arsenic presented in the LBNL report of 5.5 mg/kg was substituted for toxicity-based, direct-exposure screening levels presented in the Table K series of this appendix (Refer to the Table A-D series). At sites where this value is exceeded, additional review of background concentrations of arsenic should be carried out. (see also Figure 4 of Volume 1 for information on the evaluation of site-specific arsenic data.)

Previous editions of this document included soil (and groundwater) screening levels for total chromium, as well as screening levels for Cr VI and CR III. The species Cr III is most predominant in nature. Toxicity-based screening levels for total chromium were based on an assumed 1:6 ratio of Cr VI (highly toxic) to Cr III (minimally toxic), after methods presented in the USEPA Region IX Preliminary Remediation Goals (USEPA 2002). This approach has been discontinued and been replaced with reference to a typical background concentration of total chromium in Bay area soils.

The LBNL report referenced above presents a range of mean concentrations of total chromium in soil samples from the property of 1.7 mg/kg to 144 mg/kg, with an arithmetic mean of 58 mg/kg. This is considered typical for the Bay area in general. The concentration of total chromium in soils overlying mafic and ultramafic rocks in the Bay area can, however, be significantly higher and potentially over 1,000 mg/kg. As a provisional measure, the LBNL arithmetic mean concentration of 58 mg/kg was selected as a screening level for total chromium in soil in the lookup tables (refer to the Table A-D series). Where this value is exceeded, additional review of background total chromium concentrations should be carried out. If reported levels of total chromium appear to exceed anticipated background concentrations, then soil samples should be tested for Cr VI and Cr III and the data compared to screening levels for these specific species of chromium.

3.3 Soil Screening Levels for Potential Vapor Intrusion Concerns

Soil screening levels for the evaluation of potential indoor-air impact concerns are presented in Table E-1a and referenced in the Table A-D series. As discussed in Chapter 4, the use of soil gas data and screening levels to evaluate this concern is preferred.

A spreadsheet included with guidance published by the U.S. Environmental Protection Agency (USEPA 2003a) was used to generate soil screening levels for potential indoor-air impact concerns. A summary of these screening levels is provided in Table E-1b. Correlative soil gas screening levels are provided in Table E-2. Target indoor air goals are provided in Table E-3.

The spreadsheet is based on a model presented in the document *Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors Into Buildings* (Johnson and Ettinger, 1991). The model considers both diffusive and convective flow of subsurface vapors into buildings. Summary text from the guidance document accompanying the spreadsheet is provided in Appendix 3, as is a sensitivity evaluation of the Johnson and Ettinger model. Example printouts of the model as used to calculate screening levels for this document are included in Appendix 4. A more detailed discussion of models is provided in Section 2.4 for correlative groundwater screening levels.

Input parameter values used in the soil models are noted in the example spreadsheets in Appendix 4 (see front pages). Parameter values assumed for, building characteristics and human exposure were consistent with values used in the soil indoor-air models. The aerial extent of impacted soil is assumed to be equal to the footprint of the building. The thickness of impacted soil was assumed to be 200 cm (approximately 6 feet). The soil type was assumed to be a highly permeable sand (intrinsic permeability = $1.0E-07$ cm^2). This generated a soil vapor flow rate into the building of 67 cm^3/second or 4 liters/minute. The base of the floor was assumed to immediately over impacted soil (depth to top of soil equals thickness of floor). The model is not significantly sensitive to the input "Depth To Top of Contamination" for impacted soil situated within a few meters of the ground surface.

For nonchlorinated VOCs, field experience suggests that the vapor intrusion model typically overestimates in vapor-phase concentrations of these chemicals by an order of magnitude or more, due in part to high rates of natural biodegradation. Evaluation of this issue is ongoing. To address this in the lookup tables, soil screening levels generated with the model were adjusted upwards by a factor of ten (see Table E-1b). Collection of soil gas data and concurrent use of soil gas screening levels for indoor-air impact concerns is strongly recommended for sites where this pathway may be of significant concern.

The spreadsheet calculates the theoretical emission rate of a chemical at the ground surface based on the properties of the chemical and the soil type. For highly volatile chemicals (e.g., vinyl chloride), however, an unrealistic mass of the chemical per unit area would have to be present at depth to maintain the theoretical emission rates over the assumed exposure duration. To compensate, the model spreadsheet calculates a second, a mass-balanced emission rate by dividing the total mass of the chemical in the soil per unit area by the input exposure duration. This conservatively assumes that the entire mass of the chemical directly beneath the building will ultimately be emitted into the building over the assumed exposure duration. For chemicals where the mass-balanced

vapor emission rate is lower than the theoretical emission rate, the mass-balanced emission rate is used to generate a screening level (or calculate risk).

For chemicals that are liquids under ambient conditions, upper limits on screening levels are set at the given chemicals theoretical soil saturation limit. This conforms to assumptions used in the USEPA Region IX PRGs (USEPA 2004).

The same set of screening levels developed for shallow soils were applied to deep soils (see Tables C and D of this appendix). While conservative, the parameter for depth to impacted soil does not significantly control calculated screening levels for soils within five to ten meters of the ground surface. The need to re-evaluate the use of these screening levels should be made on a site-by-site basis.

3.4 Soil Screening Levels for Groundwater Protection

Soil screening levels for groundwater protection concerns are summarized in Table G and included in summary lookup tables for both shallow and deep soils (refer to Tables A through D of this appendix). These screening levels are intended to address potential leaching of chemicals from vadose-zone soils and subsequent impact on groundwater. The soil screening levels are back calculated based on target groundwater screening levels. Target groundwater screening levels are summarized in the Table F series and discussed in Chapter 2.

The majority of the screening levels were calculated based on an empirical equation presented in guidance published by the Massachusetts DEP (MADEP 1994):

$$C_{soil} = DAF \times C_{gw} \times 0.001 \text{ mg/ug}$$

$$DAF = (6207 \times H) + (0.166 \times Koc)$$

where: DAF = SESOIL-based dilution/attenuation factor;
H = Henry's Law Constant (atm-m3/mol);
Koc = organic carbon partition coefficient (cm^3/g);
C_{soil} = leaching based soil concentration (mg/kg);
C_{gw} = target groundwater screening level (ug/L).

The algorithm was originally developed by the state of Oregon (Anderson 1992), slightly modified for use by the Massachusetts DEP (MADEP 1994) and then incorporated into the Ontario MOEE lookup table guidance (MOEE 1996). The algorithm is bsaed on a combined use of the computer applications SESOIL and AT123D. These applications model leaching of chemicals from the vadose zone and subsequent migration of the leachate to groundwater, respectively.

SESOIL models the generation and downward migration of leachate in the vadose zone. The AT123D application models the mixing of leachate with groundwater immediately below the impacted area. A more detailed discussion of the derivation and application of the SESOIL/AT123D algorithm as modified by the Massachusetts DEP and adopted for use by the Ontario MOEE is provided in Appendix 5. The algorithm is based on a three-meter thick vadose zone characterized by one meter of impacted soil sandwiched between two one-meter thick layers of clean soil. The lower layer immediately overlies groundwater. All vadose-zone soil is conservatively assumed to be very permeable sand that freely allows the migration of leachate to groundwater. The organic carbon content of the soil is assumed to be 0.1%. (Note that this is more conservative than the 0.6% organic carbon content assumed in the direct-exposure models.) Mixing with groundwater is modeled over a ten-meter by ten-meter area. Use of a thicker assumed sequence of impacted soil would not significantly alter the results of the model given the assumed one-meter depth to groundwater.

Annual rainfall is assumed to be 1,100 mm (approximately 43 inches). A total of 720 mm (28 inches) of the total rainfall is assumed to infiltrate the ground surface and reach groundwater (very conservative for most parts of the San Francisco Bay area). Biodegradation during migration of leachate to groundwater is not considered. This could cause the model to be especially over conservative for non-chlorinated, petroleum compounds. The model does, however, allow for resorption and revolatilization of chemicals from the leachate during migration based on the physio-chemical properties of the chemical and the assumed soil properties. Groundwater is assumed to flow at a moderate rate of approximately 73 meters (240 feet) per year. The concentration of a chemical in leachate is assumed to be further reduced upon mixing of the leachate with groundwater (dilution factor approximately 3).

For moderately volatile and sorptive chemicals (e.g., benzene), screening levels developed using the SESOIL-derived algorithm are similar to screening levels generated using the full SESOIL application under a scenario where impacted soil is within a few meters of groundwater (e.g., HIDOH 1995, carried out by the principal editor of this document). Comparison to screening levels developed by full but still conservative use of SESOIL suggests, however, that the simplified algorithm may be excessively conservative in the following cases:

- Leaching of highly volatile chemicals (e.g., vinyl chloride);

- Leaching of highly sorptive chemicals (e.g., polynuclear aromatic hydrocarbons);

- Leaching of highly biodegradable chemicals (e.g., common petroleum compounds);

- Sites where the depth to groundwater is greater than ten meters below the base of the impacted soil.

The depth-to-groundwater factor is particularly important for chemicals that exhibit one or more of the above noted characteristics. As the distance between the base of impacted

soil and the top of groundwater increases, there is additional time and area for chemicals to volatilize out of the leachate, resorb to soil particles or degrade by naturally occurring biological processes. Site-specific evaluation of the potential for leaching of chemicals from soil may be warranted in such cases (including more rigorous modeling, laboratory leaching tests, groundwater monitoring, etc.).

SESOIL modeling carried out by the Hawai'i Department of Health (HIDOH 1995) suggests that chemicals with sorption coefficients greater than 30,000 cm^3/g will be essentially immobile in the surface under normal soil conditions and not likely to impact groundwater. The SESOIL models were run conservatively assuming an annual rainfall of 400 cm/year (158 inches/year), an infiltration rate of 144 cm/year (57 inches/year) and very permeable soil overlying fractured bedrock.

Based on modeling studies as well as field experience in general, screening levels for chemicals with sorption coefficients greater than 30,000 cm^3/g were therefore set at the theoretical soil saturation level for that chemical if higher than the screening level generated by use of the SESOIL algorithm (refer to Table G). The equation and assumptions used to calculate the saturation levels is presented and discussed in Appendix 2. Exceptions to this approach were the chemicals pentachlorophenol and bis(2-ethylhexyl)phthalate, both of which have a solubility significantly higher than the remainder of the highly sorptive chemicals (see Table J). Leaching based screening levels for these chemicals were developed using only the SESOIL algorithm described above (see Table G).

The majority of PCBs releases identified in the Bay Area are related to 1242 to 1260 range Arochlors. The default koc of 33,000 cm3/g presented in Table J was considered to be adequately conservative for this range and used in the leaching model. For less chlorinated PCB mixtures, a site-specific evaluation of potential leaching concerns and even possible vapor emission concerns is required.

Leaching based screening levels were generated only for chemicals considered to be significantly soluble and mobile in groundwater under normal, ambient conditions (e.g., pH 5.0 to 9.0 and normal redox conditions). Leaching based soil screening levels were not developed for metals. Leaching of metals from soil is highly dependent on the species of the metal present and the geochemical nature of the soil. At sites where physio-chemical conditions may promote enhanced leaching of metals and other chemicals from soils or waste piles (e.g., mining related wastes), the use of laboratory-based leaching tests is recommended (refer to Section 3.3.3 in Volume 1).

Leaching based soil screening levels were developed for perchlorate (ClO4). Perchlorate, a salt, is not significantly sorptive, volatile or biodegradable under normal conditions. Use of the SESOIL/AT123D algorithm was therefore not considered appropriate. As an alternative, a simple, chemical partitioning model presented in the USEPA Soil Screening Level Guidance document was referred to (USEPA 1996a, 2001):

$$Csoil = Cwater \times \left(\left(Koc \times foc \right) + \left(\frac{\theta w + \left(\theta a \times H' \right)}{\rho b} \right) \right) \times DAF$$

where: C_{soil} = Soil screening level for leaching concerns;

C_{water} = Target dissolved-phase concentration of chemical;

Koc = Sorption coefficient;

foc = fraction organic carbon in soil;

Theta$_w$ = water-filled porosity;

Theta$_a$ = air-filled porosity;

H' = Dimensionless Henry's Number constant;

p_b = Soil bulk density;

DAF = Dilution/Attenuation Factor

This model can be used to backcalculate the total soil concentration of a chemical based on a target dissolved-phase concentration of the chemical in the soil (i.e., concentration in leachate). For perchlorate, koc and H' are presumed to be zero and the equation reduces to:

$$Csoil = Cwater \times \left(\frac{\theta w}{\rho b} \right) \times DAF$$

The default water-filled porosity in the models is 0.15 and the default soil bulk density is 1.5. Based on groundwater screening levels for perchlorate of 3.6 ug/L for drinking water resources and 600 ug/L for non-drinking water resources (refer to Tables F-1a and F-1b), leaching based soil screening levels of 0.00036 mg/kg and 0.06 mg/kg are generated, respectively. A dilution/attenuation factor of 20 was incorporated to account for mixing of leachate with groundwater (USEPA 1996a, 2001). This yielded final soil screening levels for leaching concerns for perclorate of 0.007 mg/kg and 1.2 mg/kg (refer to Table G). Laboratory-based tests are recommended for more site-specific analysis of potential leaching of perchlorate from soil.

3.5 Soil Screening Levels for Terrestrial Habitats

Soil screening levels for the protection of terrestrial flora and fauna are included in summary ESL tables for shallow soils in both the "Residential" and "Commercial/Industrial Only" land-use scenarios (Tables A-1, A-2, B-1 and B-2 of this appendix). The screening levels were taken directly from guidance developed by the Ontario Ministry of Environment and Energy (MOEE 1996). Screening levels were available for heavy metals and some high-molecular-weight organic compounds and pesticides.

The MOEE guidance is primarily a compilation of criteria published by environmental agencies in Canada and elsewhere and is an update to previous guidance (e.g., MOEE 1991; CCME 1994). Ecological effects-based soil values developed by the Dutch government (Vegter 1993; van den Berg 1993) were in particular reviewed for inclusion in the MOEE guidance. The Netherland "C" values referenced are intended to represent the concentration of a chemical in soil at which the No Observed Effects Concentration for 50% of the target ecological species would be exceeded. Earlier versions of the Canadian and Dutch guidance are presented in the U. S. Fish and Wildlife Service document *Evaluation of Soil Contamination* (USFWS 1990). Pertinent sections from the MOEE guidance are presented in Appendix 6.

Soil screening levels for terrestrial ecological concerns can be highly specific to the species of fauna or flora potentially impacted as well as the specific form of the metal present and the geochemistry of the soil. The Ontario MOEE intended use of the screening levels over a broad range of land-use scenarios, including residential land use, agricultural and parkland. For the purposes of consideration in the Tier 1 lookup tables, however, the screening levels are considered to be adequate only for general screening purposes in and around developed, urban areas.

The screening levels are not intended for use in areas where a significant risk to endangered or threatened species may exist or where there is a potentially significant threat to terrestrial ecological receptors that extends beyond the general boundary of a subject site. This could include sites that are adjacent to wetlands, streams, rivers, lakes, ponds or marine shoreline or sites that otherwise contain or border areas where protected or endangered species may be present. Potential impacts to sediment are also not addressed. The need for a detailed risk assessment should be evaluated on a site-by-site basis for areas where significant ecological concerns may exist. Notification to the Natural Resource Trustee Agencies (including the state Department of Toxics Substances Control and Department of Fish and Game and the federal Fish and Wildlife Service, Department of the Interior and National Oceanic and Atmospheric Administration) may also be required, particularly if the release of a hazardous substance may impact bodies of surface water.

3.6 Soil Ceiling Levels For Gross Contamination Concerns

Ceiling levels for gross contamination concerns are presented in each of the ESL summary tables for soil. These screening levels are intended to be protective against odor and other nuisance and aesthetic concerns, as well as restrict the presence of potentially mobile, free product and limit the overall degradation of soil quality (i.e., "gross contamination"). The selection of soil ceiling levels was based on methods originally published by the Massachusetts DEP (MADEP 1994) and also used by the Ontario MOEE (MOEE 1996), as described in the Table H series of this appendix.

Odor Thresholds presented in the Table H series are intended to represent the concentration of a chemical in air at which 50% of the population can detect a chemical odor. An "Odor Index" for a chemical is calculated by dividing the chemicals vapor pressure (in Torr, at 20-30 degrees Celsius) by its odor threshold (in ppm-volume, see Tables H-2 and H-3). This provides a relative ranking of chemicals for potential nuisance concerns. As summarized in H-2 (shallow soils) and H-3 (deep soils), ceiling levels were then selected based a comparison of a chemicals vapor pressure and odor index to a table of generic screening levels (Tables H-1). For chemicals that are liquids under ambient conditions, the final ceiling level was selected as the lowest of the generic level from Table H-1 and the chemicals theoretical saturation level in soil (see Appendix 2). This was intended to prevent the presence of mobile, free product in the subsurface.

TABLE 3-1. ENVIRONMENTAL CONCERNS CONSIDERED IN SOIL ESLs.

Category	Human Health (Direct-Exposure)	Human Health (Indoor-Air Impact)	*Groundwater Protection (Drinking Water Resource Threatened)	*Groundwater Protection (Drinking Water Resource NOT Threatened)	Ecological Concerns (Terrestrial Receptors)	Ceiling Values
Table A						
Residential Land Use	X	X	X	X	X	X
Commercial/Industrial Land Use Only	X	X	X	X	X	X
Table B						
Residential Land Use	X	X		X	X	X
Commercial/Industrial Land Use Only	X	X		X	X	X
Table C						
Residential Land Use	X	X	X	X		X
Commercial/Industrial Land Use Only	X	X	X	X		X
Table D						
Residential Land Use	X	X		X		X
Commercial/Industrial Land Use Only	X	X		X		X

*Groundwater protection concerns not related to drinking water include discharge to surface water, indoor-air impacts, and ceiling levels (nuisance concerns, etc.).
Table A - Shallow Soils Overlying Drinking Water Resource
Table B - Shallow Soils NOT Overlying Drinking Water Resource
Table C - Deep Soils Overlying Drinking Water Resource
Table D - Deep Soils NOT Overlying Drinking Water Resource

4

Indoor Air and Soil Gas Screening Levels

4.1 Introduction

The USEPA spreadsheet version of the Johnson & Ettinger model for soil gas intrusion into buildings (USEPA 2003a) was used to develop indoor air and soil gas screening levels for volatile chemicals. Example printouts of the model are included in Appendix 4. The model can be condensed into three simple steps: 1) calculation of a target indoor-air goal based on input exposure assumptions and chemical toxicity factors; 2) calculation of soil gas-to-indoor air attenuation factors based on a comparison of vapor flow rates into a building and air flow rates through the building and 3) calculation of a soil gas screening level. A summary of these steps is provided below. A more detailed discussion of the model is provided in Appendix 3.

4.2 Indoor Air Screening Levels

Indoor air screening levels were calculated using the following equation incorporated in the model:

Carcinogens:

$$\text{Cia} = \left(\frac{\text{TR} \times \text{ATc} \times 365\,\text{days/yr}}{\text{URF} \times \text{EF} \times \text{ED}} \right)$$

Noncarcinogens:

$$\text{Cia} = \left(\frac{\text{THQ} \times \text{ATnc} \times 365\,\text{days/yr}}{\left(\dfrac{1}{\text{RfC}} \right) \times \text{EF} \times \text{ED}} \right)$$

where:

    Cia = Target indoor air concentration;

    TR = Target risk (carcinogens);

    THQ = Target hazard quotient (noncarcinogens);

    ATc = Averaging time for carcinogens;

    ATnc = Averaging time for noncarcinogens;

    URF = Unit risk factor for carcinogens (carcinogens);

    RfC = Reference concentration (noncarcinogens);

    EF = Exposure frequency;

    ED = Exposure duration.

A summary of the indoor-air goals calculated is provided in Table E-3. For carcinogenic effects, the target excess cancer risk was set at 10^{-6}. For noncarcinogenic effects, the target Hazard Quotient was set at 0.2 for all chemicals except TPH, where a hazard Quotient of 0.5 was used (refer also to Section 1.3). Inhalation toxicity factors for volatile chemicals are summarized in Appendix 4 (VLOOKUP worksheet). Input exposure assumptions were identical to those assumed for direct-exposure models (refer to summary in Appendix 2 and DATAENTER worksheets in Appendix 4).

4.3   Soil Gas Screening Levels

Building design parameter values used in the groundwater and soil vapor-emission models were retained for use in the soil gas model (one story, 100m^2 foundation area; refer to Section 2.4 and DATAENTER worksheets in Appendix 4). The spreadsheet models the intrusion of soil gas situated immediately beneath the slab-on-grade foundation into the overlying building ("Soil Gas Sampling Depth Below Grade" = 15 cm). Soil underlying the building was assumed to be a very permeable fill material. Default parameter values for a "sand" soil type were used in the model.

Based on the input building characteristics and soil type, a vapor emission rate of 67 cm^3/sec was generated (Qsoil, equivalent to 4.0 liters/minute). Indoor-air exchange rates of 1.0 times-per-hour and 2.0 times-per-hour were assumed for residences and commercial/industrial buildings, respectively. Given the assumed dimensions of 10m x 10m x 2.44 m for the modeled buildings, indoor-air "flow rates" of approximately 4,000 L/minute for residences and 8,000 L/minute for commercial/industrial buildings were generated.

Calculation of a soil gas-to-indoor air attenuation factor (AF) essentially reduces to:

$$AF = \left(\frac{\text{vapor intrusion rate}}{\text{vapor intrusion rate} + \text{indoor air flow rate}} \right).$$

For residences, a soil gas-to-indoor air attenuation factor of approximately 0.001 (1/1000) was calculated. For commercial/industrial buildings, a soil gas-to-indoor air attenuation factor of approximately 0.0005 (1/2000) was calculated. The shallow, assumed depth to soil gas and predominance of advective flow over diffusive flow effectively negates small differences in the fate and transport of individual chemicals. This allows the calculated attenuation factors to be used in a generic fashion for all volatile chemicals. Soil-gas screening levels (C_{sg}) are subsequently calculated as:

$$Csg = \left(\frac{\text{Indoor Air Goal}}{AF} \right).$$

A summary of soil-gas screening levels for volatile chemicals is provided in Tables E-2.

Note that soil-gas screening levels do not take into account the actual mass of the chemical present and could be overly conservative for the evaluation of long-term impacts to indoor air. At sites where a limited amount of impacted soil or groundwater is present, the concentration of the chemical in soil gas can be expected to decrease over time as the supply of the chemical is depleted. This would lead to steadily decreasing impacts to indoor air. Thus, while impacts to indoor air may initially exceed target goals, average, long-term impacts could conceivably fall below these goals.

This issue should be evaluated on a site-by-site basis as needed. As a conservative measure, and for the purpose of this screening levels document, it is recommended that indoor-air goals be used as "not-to-exceed" criteria and adjustment of models and soil gas to address potential mass-balance not be carried out in the absence of strong site data. This issue is currently under reviewed. Additional information will be incorporated into the ESL document as available.

5

Soil And Groundwater Screening Levels For TPH

5.1   Introduction

The selection of Total Petroleum Hydrocarbons (TPH) soil and groundwater screening levels for use in this document is described below. As discussed in the Volume 1, the use of ESLs as final "cleanup levels" for petroleum-related compounds that are known to be highly biodegradable may be unnecessarily conservative. This is especially true for leaching based soil screening levels for TPH and petroleum-related compounds. Final cleanup levels should be evaluated on a site-specific basis and in conjunction with guidance from the overseeing regulatory agency.

Petroleum is a complex mixture of hundreds of different compounds composed of hydrogen and carbon (i.e., "hydrocarbon" compounds). For the purposes of this document, petroleum mixtures are subdivided into "gasolines", "middles distillates" and "residual fuels", following the methodology used by the American Petroleum Institute (API 1994).   **Gasolines** are defined as petroleum mixtures characterized by a predominance of branched alkanes and aromatic hydrocarbons with carbon ranges of C6 to C12 and lesser amounts of straight-chain alkanes, alkenes and cycloalkanes of the same carbon range. **Middle distillates** (e.g., kerosene, diesel fuel, home heating fuel, jet fuel, etc.) are characterized by a wider variety of straight, branched and cyclic alkanes, polynuclear aromatic hydrocarbons (PAHs, especially naphthalenes an methyl naphthalenes) and heterocyclic compounds with carbon ranges of approximately C9 to C25. **Residual fuels** (e.g., fuel oil Nos. 4, 5, and 6, lubricating oils, "waste oils", "oil and grease," asphalts, etc.) are characterized complex, polar PAHs, naphthenoaromatics, asphaltenes and other high-molecular-weight, saturated hydrocarbon compounds with carbon ranges that in general fall between C24 and C40.

Laboratory analysis for TPH as gasolines and middle distillates is commonly carried out using EPA Method 8015 (or equivalent) modified for "gasoline-range" organics ("Volatile Fuel Hydrocarbons") and "diesel-range" organics ("Extractable Fuel

Hydrocarbons"), respectively. Analysis for TPH as residual fuels up to the C40 carbon range can generally be carried out by gas chromatograph methods (e.g., Method 8015 modified for "motor oil" and "waste oil" range organics) but can also include the use of infrared or gravimetric methods. More detailed information on analytical methods for TPH and other chemicals can be obtained from environmental laboratories or the overseeing regulatory agency.

Laboratory measurement and assessment of each individual compound within a petroleum mixture is technically complex and generally not feasible or appropriate under most circumstances. More importantly, data regarding the physio-chemical and toxicity characteristics of the majority of petroleum compounds are lacking. Impacts to soil and water from petroleum mixtures are instead evaluated in terms of both TPH and well characterized "indicator chemicals" (e.g., benzene, toluene, ethylbenzene, xylenes and targeted PAHs). Indicator chemicals typically recommended for petroleum mixtures include (after CalEPA 1996):

Monocyclic Aromatic Compounds (primarily gasolines and middle distillates)
- benzene
- ethylbenzene
- toluene
- xylene

Fuel additives (primarily gasolines)
- MTBE
- other oxygenates as necessary

Polycyclic Aromatic Compounds (primarily middle distillates and residual fuels)
- methylnaphthalene (1- and 2-)
- acenaphthene
- acenaphthylene
- anthracene
- benzo(a)anthracene
- benzo(b)fluoranthene
- benzo(g,h,i)perylene
- benzo(a)pyrene
- benzo(k)fluoranthene
- chrysene
- dibenzo(a,h)anthracene
- fluoranthene
- fluorene
- indeno(1,2,3)pyrene
- naphthalene
- phenanthrene
- pyrene

The TPH ESLs should be used in conjunction with ESLs for these chemicals. Note that volatile chemicals such as butylbenzene, isopropyl benzene, isopropyl toluene and trimethylbenzenes are often reported in analyses of gasoline and other light-end

petroleum products. These chemicals are collectively addressed under screening levels for "TPH" and generally do not need to be evaluated separately.

Soil and groundwater impacted by releases of waste oil may also require testing for heavy metals and chemicals such as chlorinated solvents and PCBs. Screening levels for these chemicals are included in the lookup tables.

5.2 TPH Screening Levels For Groundwater

Regulatory drinking water standards for TPH and petroleum in general have not been developed. For the purposes of this document, the TPH-diesel taste and odor threshold of 100 ug/L referenced in the technical document *A Compilation of Water Quality Goals* (RWQCBCV 2000) was used as the drinking water screening level for all categories of TPH (see Table F-3). Screening levels for benzene and related light-weight hydrocarbon compounds are considered to provide adequate additional protection of drinking water concerns for gasoline-impacted groundwater when used in conjunction with the TPH screening level of 100 ug/L. For the protection of aquatic life, a screening level of 500 ug/L was selected for TPH-gasoline in freshwater and 3,700 ug/L in saltwater (see Table F-4b). A single screening level of 640 ug/L was selected for TPH-diesel and TPH-residual fuels in both freshwater and saltwater. The freshwater screening level for TPH-gasoline is based on a summary of available eco-toxicity data compiled for use at the Presidio of San Francisco under Board Order 96-070 (RWQCBSF 1998b, Montgomery Watson 1999). The TPH-gasoline criteria for saltwater and the TPH criteria for diesel and residual fuels in general are based on screening levels developed for use at the San Francisco Airport under Regional Water Board Order No. 99-045 (RWQCBSF 1999a).

The groundwater nuisance and odor concerns screening level of 5,000 ug/L for TPH (all categories) noted in the Table I series for nondrinking water was taken directly from Massachusetts DEP risk assessment guidance (MADEP 1997a,b). This also corresponds with the approximate solubility of diesel fuel and light motor oil in fresh water (ATSDR 2001a) and is intended to address potential nuisance issues (odors, etc.) if discharged to surface water, as required under the Basin Plan (RWQCBSF 1995). The TPH ceiling levels for gross contamination concerns are based on 1/2 the solubility of the respective TPH categories (refer to Table I series). The solubility of gasoline in freshwater is approximately 150,000 ug/L. The solubility of diesel range and heavier fuels is assumed to be approximately 5,000 ug/L. These screening levels are intended to highlight the potential presence of free product on groundwater.

5.3 TPH Screening Levels For Soil

5.3.1 TPH (gasolines, middle distillates)

Soil screening levels for lighter fractions of petroleum (gasolines, middle distillates) were selected based on a "surrogate" approach developed by the Massachusetts Department of

Environmental Protection (Hutchinson et. al 1996; MADEP 1997a,b). The Massachusetts approach is similar to guidance developed by the Total Petroleum Hydrocarbon Working Group (TPHCWG 1998).

Massachusetts used six distinct groups of petroleum hydrocarbon compounds with similar carbon makeups and similar physio-chemical and toxicity characteristics to collectively describe the spectrum of all possible petroleum product mixtures (referred to as "carbon ranges"). For example, petroleum-related aromatic compound with five to 22 carbon atoms are grouped in the C11-C22 aromatic carbon range. Surrogate toxicity factors and physio-chemical constants were chosen for each carbon range group. These constants were then used to develop environmental soil and groundwater screening levels for each carbon range in the same manner as done for individual chemicals (see Chapters 2 and 3).

Due to the relatively high mobility of compounds included within the C11-C22 aromatics range fraction and the general predominance of these compounds in lighter-weight fuels, Massachusetts elected to use toxicity factors and physio-chemical constants for this carbon range as a "surrogate" for TPH in general. The same approach was adopted for use in this document. This could be potentially under conservative for gasoline-range mixtures with a predominance of more lighter and more mobile compounds. The use of conservative target indicator compounds (e.g., BTEX) in conjunction with the TPH screening level is assumed to adequately address this issue, however.

Massachusetts selected an oral reference dose (RfD) of 0.03 mg/kg-d and an inhalation reference dose of 0.14 mg/kg-d for the C11-C22 aromatics fraction, based in part on comparison to the Massachusetts RfDs for pyrene. An oral RfD of 0.03 mg/kg-d is also used in the USEPA PRGs for pyrene (see table J). The TPH Working Group selected a slightly less conservative oral RfD of 0.04 mg/kg-d and inhalation RfD of 0.06 mg/kg-d (based on Reference Concentration of 0.20 mg/m^3) for the same carbon range group (THPWG 1998). In this document, the reference doses developed by MADEP were ultimately used to generate direct-exposure soil screening levels for TPH (refer to Tables K-1, K-2 and K-3). The screening levels are based on a target hazard quotient of 0.5 (see Section 1.3).

Massachusetts developed generic physio-chemical constants for the C11-C22 aromatics carbon range fraction based on a review of compounds included within this fraction. These constants were adopted in this document to develop a soil leaching screening level for TPH as gasolines and middle distillates (see Table G). The TPH soil screening level calculated for protection of drinking water (rounded to 100 mg/kg) is coincidental with screening levels presented in other technical documents prepared by local regulatory agencies (RWQCBSF 1990; RWQCBLA 1996). Similarly, the soil screening level calculated for protection of surface water habitats (rounded to 400 mg/kg (gasolines) and 500 mg/kg (middle distillates)) is coincidental with the screening level developed for use in the Board Order for the San Francisco Airport (RWQCB 1999a).

Ceiling levels for nuisance and other gross contamination concerns developed by Massachusetts for TPH as gasoline and diesel (latter included under "middle distillates") were modified for use in this document (MADEP 1997a,b, refer to Table H series). Based on calculated "odor indexes", a shallow soil ceiling level of 100 mg/kg was selected for residential land-use scenarios and a ceiling level of 500 mg/kg was selected for commercial/industrial land-use (both categories of TPH). For deep soils, a ceiling level of 5,000 mg/kg was retained (primarily intended to prevent the presence of potentially mobile free product in soil).

5.3.2 TPH (residual fuels)

Direct-exposure screening levels developed for TPH as gasoline and as middle distillates were retained for use with TPH as residual fuels (refer to Table K-1). Following Massachusetts DEP guidance (MADEP 1997a,b), ceiling levels for gross contamination concerns of 500 mg/kg and 2,500 mg/kg were selected for residential and commercial/industrial shallow soils, respectively. The Massachusetts DEP ceiling level of 5,000 mg/kg was used for deep soils.

The Massachusetts DEP did not develop specific screening levels for leaching of heavy hydrocarbons from soil (refer to C19-C36 carbon range summary in Appendix 7). Residual fuels are by definition characterized by a predominance hydrocarbon compounds with carbon ranges greater than C24. These compounds are considered to be substantially less mobile in the subsurface that hydrocarbon compounds that make up the lighter-weight petroleum mixtures. For TPH that is characterized by a predominance of C23-C32 carbon range compounds, the Los Angeles Regional Water Board proposes a screening level of 1,000 mg/kg for protection of drinking water resources (RWQCBLA 1996). This screening level was adopted for use in this document (refer to Table G). The target TPH screening level for groundwater was not specifically stated but is presumably 100 ug/L or less.

The Los Angeles Regional Water Board did not present a similar screening level for potential leaching of TPH from soil and subsequent discharge of impacted groundwater to a body of surface water. Although conservative, the Los Angeles TPH soil leaching screening level 1,000 mg/kg was retained for this purpose (see Table G, refer also to Section 3.4).

5.3.3 Ethanol

Gasoline formulations in California are anticipated to include an increasing proportion of ethanol in the near future. Soil, soil gas, indoor air and groundwater screening levels for ethanol have therefore been added to the ESL document. Human-health, chronic toxicity factors for ethanol have not been developed. Ethanol is not considered to pose chronic health risks at the low doses posed by exposure to contaminated soil and groundwater. The screening levels are therefore based only on nuisance and gross contamination

concerns. "Ceiling Levels" for these concerns are presented in Tables H (soil and indoor air) and I (groundwater and surface water). The final screening level for each of the groundwater categories is based on an "Upper Limit" of 50 mg/L (Table I series, see also Tables F-1a and F-1b). The final soil screening level presented in each of the soil categories of 45 mg/kg is based on the protection of groundwater to the noted target groundwater screening level (Table G, see also Table A-D series). The leaching based screening level was adjusted upwards by a factor of ten to take into account the high, anticipated biodegradation rate of ethanol in the environment. The adequacy of this screening level should be further evaluated in the field as appropriate (e.g., sites near producing water wells or bodies of surface water). The indoor air screening level of 19,200 ug/m^3 (10 ppmv) is based on the published odor threshold potential for ethanol (Table H series, see also Table E-3). This concentration is well below the OSHA Permissible Exposure Limit of 1,000 ppmv for workers.

Although highly mobile in the environment, ethanol is also highly biodegradable, not significantly toxic in low dose, and is likely to only persist in the presence of other, more toxic components of gasoline, including benzene (Ulrich 1999). An assessment and cleanup of contaminated soil and groundwater to address health threats posed by associated compounds is expected to address any potential health concerns posed by exposure to residual ethanol in soil, air or water.

6

Other Issues

6.1 Laboratory Reporting Levels and Background Concentrations

Laboratory method reporting limits and background concentrations of chemicals were not directly considered in development of the lookup tables. As discussed in Volume 1 of this document, however, reporting limits approved by the overseeing regulatory agency should be used in place of the ESLs presented in this document when higher. An ESL should similarly be replaced with the natural background concentration of the chemical if the background value is higher.

Arsenic and chromium are often naturally present in Bay area soils at levels above toxicity-based screening levels. Based on a review of soil data for the Bay area (e.g., LBNL 2002 and numerous site investigation reports), median background concentrations for these chemicals were selected to be 5.5 mg/kg and 58 mg/kg, respectively, for use in this document. Final soil screening levels for these metals are based on the assumed background concentrations if lower then the risk-based screening level (refer to Tables A-D). A more detailed evaluation of background concentrations of metals in Bay area soil will be included in future updates of this document. Suggestions for the evaluation of arsenic in soil are provided in Section 2.9 and Figure 4 of Volume 1.

6.2 Reporting of Soil Data

Soil data are calculated by dividing the mass of the chemical of concern detected in the soil by the total weight of the soil. The weight of a soil sample can be measured on either a dry-weight basis (i.e., excluding the weight of water in the soil sample) or a wet-weight basis (i.e., including the weight of water in the soil sample). For a typical soil sample, the inclusion of soil moisture in calculation of chemical concentrations can effectively reduce the reported concentrations by 10-20% or greater, simply because the measured total weight of the sample is greater.

From a site-investigation and risk assessment-standpoint, a difference in the reported concentration of a chemical of 10-20% is not necessarily significant. **For consistency**

and for comparison to soil ESLs presented in this document, however, soil data should be reported on dry-weight basis. This is in part because soil ingestion rates assumed in direct-exposure models (see Appendices 1 and 2) are based on dry-weight studies (USEPA 1997). Comparison of wet-weight data to direct-exposure screening level would technically require adjustment of the direct-exposure screening levels to reflect wet weight-based soil ingestion rates. A site-specific consideration of wet-weight soil data will be dependent on assumptions in the model(s) being used to evaluate risk or generate environmental screening levels. Existing wet-weight soil data may not necessarily need to be adjusted prior to comparison to the ESLs unless the introduced bias is considered to be a potentially significant factor at the site. (Note that sediment data should also be reported on a dry-weight basis.)

6.3   Additional Soil Parameters

For surface soils, screening levels are also presented for Electrical Conductivity and Sodium Absorption Ratio (after MOEE 1996). Both parameters are intended primarily for evaluation of soils impacted by brines (e.g., from oil and gas field discharges). The Sodium Absorption Ratio reflects the amount of sodium present in the soil with respect to other major cations. An overabundance of sodium can inhibit plant uptake of nutrients, reduce soil cohesion and cause excessive erosion of topsoil. The electrical conductivity of a soil reflects the total concentration of soluble salts in the soil solution. A high concentration of salts can have a significant influence on osmotic processes involved in plant growth. (NOTE: The Electrical Conductivity screening levels assumes a fixed 2:1 water:soil solution in the laboratory method. The USEPA Laboratory Method 120.1(Mod) normally calls for a 1:1 dilution ratio, i.e., extract from a saturated sample. The laboratory should be notified of the need for a 2:1 dilution ratio prior to analysis.)

6.4   Degradation to Daughter Products

Consideration of the degradation of a chemical to more toxic daughter products, such as the breakdown of tetrachloroethylene to vinyl chloride, is an important part of site investigations. Tier 1 lookup tables generated by some regulatory agencies incorporate a very conservative assumption that the entire mass of a parent chemical will be eventually be transformed to the daughter product at the same initial concentration (e.g., MADEP 1994, MOEE 1996). They in turn reduce the initially derived screening levels for these parent compounds to reflect the screening levels for the more toxic daughter product, without taking into account issues such as the lower molecular weights (and lower ultimate masses) of the daughter products. While the need to monitor for degradation byproducts is well founded, it is felt that the above approach is overly conservative in most cases and not reflective of naturally occurring conditions. In the case of tetrachlorethylene, for example, degradation to vinyl chloride and further degradation of vinyl chloride to non-toxic ethene gas (and ultimately carbon dioxide and water) can be expected to be a steady-state process at sites where degradation is occurring, removing a portion of the vinyl chloride as it is generated. At most release sites this process has already been initiated, and the already conservative screening levels for individual,

primary compounds are considered to be adequately protective of human health and the environment. The need to reconsider this assumption should be evaluated on a site-by-site basis.

This issue is currently be evaluated in more detail. It should be pointed out that at some sites degradation of chlorinated solvents in groundwater is minimal (e.g., PCE) but levels of daughter products in soil gas are very elevated (e.g., vinyl chloride). This emphasizes the need to collect soil gas data at sites where vapor intrusion is of potential concern.

7

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FIGURES
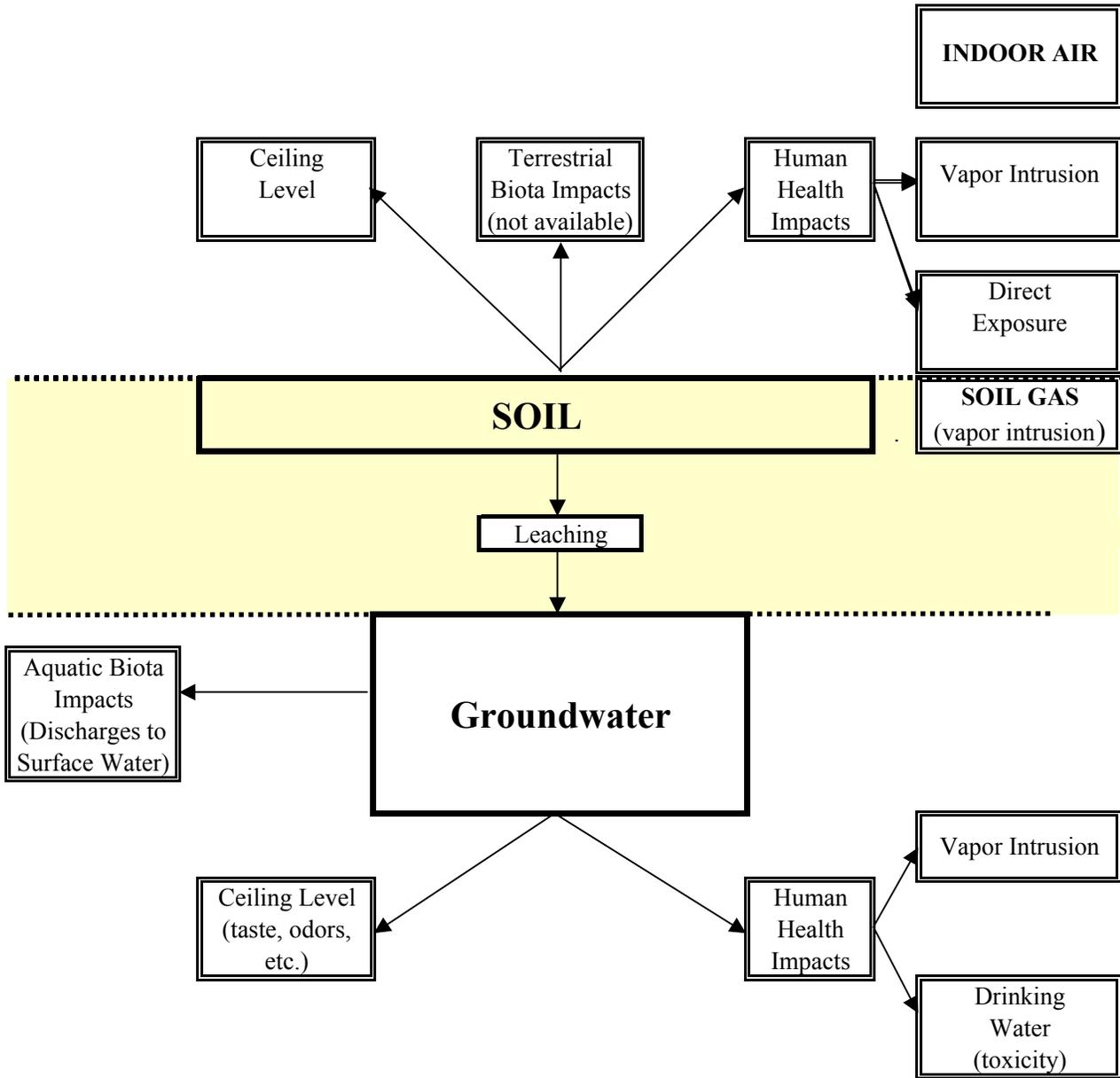
Figure 1. Summary of human health and environmental concerns considered in screening levels. Additional site-specific considerations include groundwater beneficial use, depth to impacted soil, soil type and land use. This figure is intended for Tier 1 and Tier 2 assessments only. Evaluation of environmental concerns not shown requires site-specific assessment.
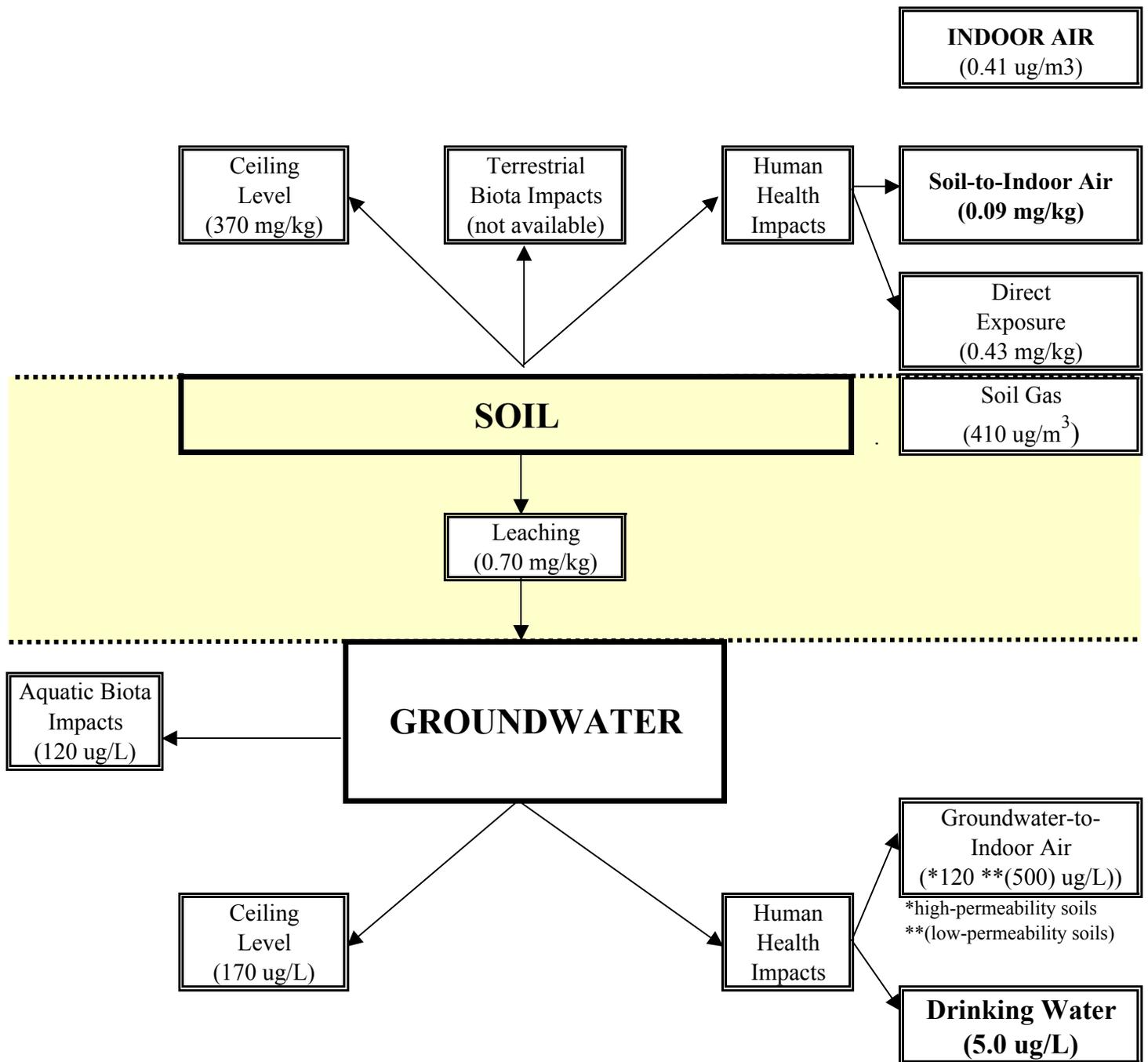
Figure 2. Summary of individual screening levels used to select final, Tier 1 ESLs for tetrachloroethylene in soils situated within ten feet of the ground surface and in groundwater that is a current or potential source of drinking water, based on a residential land-use scenario. Final ESLs presented in Volume 1 summary tables are the lowest of the individual screening levels. Potential impact to indoor air drives selection of the final soil ESL (0.09 mg/kg). For groundwater, drinking water toxicity concerns drive selection of final ESL (5.0 ug/L). Groundwater-to-indoor air screening levels for low-permeability soils not shown in summary lookup tables (refer to Table E-1a).

TABLES

TABLE A-1. ¹SHALLOW SOIL SCREENING LEVELS (≤3m bgs)
²RESIDENTIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

²RESIDENTIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Substitute Direct Exposure Value	Substitute Direct Exposure Basis	Direct Exposure Table K-1	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
ACENAPHTHENE	1.6E+01	1.0E+03	-			6.0E+02	1.3E+02	1.6E+01
ACENAPHTHYLENE	1.3E+01	5.0E+02	-	4.4E+02	Fluorene	4.4E+02	(Use soil gas)	1.3E+01
ACETONE	5.0E-01	5.0E+02	-			2.7E+03	1.4E+03	5.0E-01
ALDRIN	3.2E-02	1.0E+03	3.5E-01			3.2E-02		5.0E+00
ANTHRACENE	2.8E+00	5.0E+02	4.0E+01			3.5E+03	6.1E+00	2.8E+00
ANTIMONY	6.1E+00	1.0E+03	2.0E+01			6.1E+00		
ARSENIC	5.5E+00	1.0E+03	2.0E+01	5.5	Background	5.5E+00		
BARIUM	7.5E+02	1.0E+03	7.5E+02			1.0E+03		
BENZENE	4.4E-02	5.0E+02	2.5E-01			1.8E-01	1.8E-01	4.4E-02
BENZO(a)ANTHRACENE	3.8E-01	5.0E+02	4.0E+01			3.8E-01		1.2E+01
BENZO(b)FLUORANTHENE	3.8E-01	5.0E+02				3.8E-01		4.6E+01
BENZO(k)FLUORANTHENE	3.8E-01	5.0E+02	4.0E+01			3.8E-01		2.7E+00
BENZO(g,h,i)PERYLENE	2.7E+01	5.0E+02	4.0E+01	4.6E+02	Fluoranthene	4.6E+02		2.7E+01
BENZO(a)PYRENE	3.8E-02	5.0E+02	4.0E+01			3.8E-02		1.3E+02
BERYLLIUM	4.0E+00	1.0E+03	4.0E+00			2.9E+01		
BIPHENYL, 1,1-	6.5E-01	5.0E+02				4.9E+02	(Use soil gas)	6.5E-01
BIS(2-CHLOROETHYL)ETHER	1.8E-04	5.0E+02				8.5E-02	3.7E-03	1.8E-04
BIS(2-CHLOROISOPROPYL)ETHER	5.4E-03	5.0E+02				2.6E+00	(Use soil gas)	5.4E-03
BIS(2-ETHYLHEXYL)PHTHALATE	6.6E+01	5.0E+02				1.6E+02		6.6E+01
BORON	1.6E+00	no criteria	1.6E+00			2.4E+03		
BROMODICHLOROMETHANE	1.4E-02	1.0E+03				3.8E-01	1.4E-02	1.9E+00
BROMOFORM	2.2E+00	5.0E+02				6.1E+01		2.2E+00
BROMOMETHANE	2.2E-01	5.0E+02				7.5E-01	2.2E-01	3.9E-01
CADMIUM	1.7E+00	1.0E+03	1.2E+01			1.7E+00		
CARBON TETRACHLORIDE	1.2E-02	5.0E+02				8.9E-02	1.2E-02	1.1E-01
CHLORDANE	4.4E-01	1.0E+03				4.4E-01		1.5E-01
CHLOROANILINE, p-	5.3E-02	1.0E+03				4.9E+01		5.3E-02
CHLOROBENZENE	1.5E+00	5.0E+02	3.0E+01			2.9E+01	2.7E+00	1.5E+00
CHLOROETHANE	6.3E-01	5.0E+02				3.0E+00	6.3E-01	8.5E-01
CHLOROFORM	8.8E-01	5.0E+02				8.8E-01	1.4E+02	2.1E+00
CHLOROMETHANE	7.0E-02	1.0E+02				3.0E-01	7.0E-02	2.1E-01
CHLOROPHENOL, 2-	1.2E-02	1.0E+02	1.0E+01			1.2E+01	7.8E-01	1.2E-02
CHROMIUM (Total)	5.8E+01	1.0E+03		58	Background	5.8E+01		
CHROMIUM III	7.5E+02	1.0E+03	7.5E+02			2.3E+04		
CHROMIUM VI	1.8E+00	1.0E+03	8.0E+00			1.8E+00		
CHRYSENE	3.8E+00	1.0E+03	4.0E+01			3.8E+00		1.9E+01
COBALT	1.0E+01	1.0E+03	4.0E+01			1.0E+01		
COPPER	2.3E+02	1.0E+03	2.3E+02			6.1E+02		

TABLE A-1. ¹SHALLOW SOIL SCREENING LEVELS (≤3m bgs)
²RESIDENTIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	²RESIDENTIAL LAND USE (mg/kg) Urban Area Ecotoxicity Criteria	Human Health Substitute Direct Exposure Value	Human Health Substitute Direct Exposure Basis	Direct Exposure Table K-1	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
CYANIDE (Free)	3.6E-03	1.0E+02	-			2.4E+02		3.6E-03
DIBENZO(a,h)ANTHTRACENE	1.1E-01	5.0E+02	-			1.1E-01		9.9E+00
DIBROMOCHLOROMETHANE	1.9E-02	1.0E+02	-			9.4E-01	1.9E-02	8.3E+00
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	5.0E+02	-			2.7E-02	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	3.3E-04	5.0E+02	-			8.7E-02	7.3E-03	3.3E-04
DICHLOROBENZENE, 1,2-	1.1E+00	6.0E+02	3.0E+01			2.1E+02	8.9E+00	1.1E+00
DICHLOROBENZENE, 1,3-	7.4E+00	1.0E+02	3.0E+01			9.9E+01	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	4.6E-02	5.0E+02	3.0E+01			2.1E+00	4.6E-02	5.9E-01
DICHLOROBENZIDINE, 3,3-	7.7E-03	5.0E+02	-			4.0E-01		7.7E-03
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.3E+00	5.0E+02	-			2.3E+00		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.6E+00	5.0E+02	4.0E+00			1.6E+00		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.6E+00	1.0E+03	4.0E+00			1.6E+00		4.3E+00
DICHLOROETHANE, 1,1-	2.0E-01	5.0E+02	-			2.7E+00	3.2E-01	2.0E-01
DICHLOROETHANE, 1,2-	4.5E-03	5.0E+02	6.0E+01			3.4E-01	2.5E-02	4.5E-03
DICHLOROETHYLENE, 1,1-	1.0E+00	5.0E+02	-			2.4E+01	8.9E+00	1.0E+00
DICHLOROETHYLENE, Cis 1,2-	1.9E-01	1.0E+02	-			8.4E+00	1.6E+00	1.9E-01
DICHLOROETHYLENE, Trans 1,2-	6.7E-01	5.0E+02	-			1.4E+01	3.1E+00	6.7E-01
DICHLOROPHENOL, 2,4-	3.0E-01	5.0E+02	1.0E+01			3.7E+01		3.0E-01
DICHLOROPROPANE, 1,2-	5.1E-02	1.0E+02	-			6.3E-01	5.1E-02	1.2E-01
DICHLOROPROPENE, 1,3-	3.3E-02	5.0E+02	-			2.1E-01	3.3E-02	5.9E-02
DIELDRIN	2.3E-03	1.0E+03	4.0E+00			3.4E-02		2.3E-03
DIETHYLPHTHALATE	3.5E-02	5.0E+02	-			9.8E+03		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	5.0E+02	-			1.2E+05		3.5E-02
DIMETHYLPHENOL, 2,4-	6.7E-01	1.0E+02	-			1.4E+02	1.1E-02	6.7E-01
DINITROPHENOL, 2,4-	4.0E-02	5.0E+02	-			2.4E+01		4.0E-02
DINITROTOLUENE, 2,4-	8.5E-04	5.0E+02	-			1.6E+00		8.5E-04
1,4 DIOXANE	1.8E-03	5.0E+02	-			1.8E+01		1.8E-03
DIOXIN (2,3,7,8-TCDD)	4.6E-06	no criteria	-			4.6E-06		
ENDOSULFAN	4.6E-03	5.0E+02	-			7.3E+01		4.6E-03
ENDRIN	6.5E-04	5.0E+02	6.0E-02			4.1E+00		6.5E-04
ETHANOL	4.5E+01	5.0E+02	-				(Use soil gas)	4.5E+01
ETHYLBENZENE	3.3E+00	4.0E+02	-			4.0E+02	3.9E+02	3.3E+00
FLUORANTHENE	4.0E+01	5.0E+02	4.0E+01			4.6E+02		6.0E+01
FLUORENE	8.9E+00	5.0E+02	-			4.4E+02	1.6E+02	8.9E+00
HEPTACHLOR	1.4E-02	1.0E+03	-			1.3E-01		1.4E-02
HEPTACHLOR EPOXIDE	1.5E-02	1.0E+03	-			8.8E-02		1.5E-02
HEXACHLOROBENZENE	2.7E-01	5.0E+02	3.0E+01			2.7E-01		7.9E+02
HEXACHLOROBUTADIENE	1.0E+00	5.0E+02	-			3.7E+00		1.0E+00

TABLE A-1. ¹SHALLOW SOIL SCREENING LEVELS (≤3m bgs) ²RESIDENTIAL LAND USE

(potentially impacted groundwater IS a current or potential drinking water resource)

²RESIDENTIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health Substitute Direct Exposure — Value	Human Health Substitute Direct Exposure — Basis	Human Health Direct Exposure Table K-1	Human Health Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	5.0E+02	2.0E+00			5.0E-01		4.9E-02
HEXACHLOROETHANE	2.4E+00	5.0E+02				1.2E+01		2.4E+00
INDENO(1,2,3-cd)PYRENE	3.8E-01	5.0E+02	4.0E+01			3.8E-01		7.7E+00
LEAD	1.5E+02	1.0E+03	2.0E+02			1.50E+02		
MERCURY	3.7E+00	5.0E+02	1.0E+01			3.7E+00	(Use soil gas)	
METHOXYCHLOR	1.9E+01	5.0E+02				6.9E+01		1.9E+01
METHYLENE CHLORIDE	7.7E-02	5.0E+02	-			4.1E+00	5.2E-01	7.7E-02
METHYL ETHYL KETONE	3.9E+00	5.0E+02	-			1.4E+03	4.9E+02	3.9E+00
METHYL ISOBUTYL KETONE	2.8E+00	1.0E+02	-			1.5E+02	1.2E+02	2.8E+00
METHYL MERCURY	1.2E+00	1.0E+02	1.0E+01			1.2E+00		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	5.0E+02	-			2.6E+02	1.1E+02	2.5E-01
METHYL TERT BUTYL ETHER	2.3E-02	1.0E+02	-			3.0E+01	2.0E+00	2.3E-02
MOLYBDENUM	4.0E+01	1.0E+03	4.0E+01			7.6E+01		
NAPHTHALENE	4.6E-01	5.0E+02	4.0E+01			1.5E+00	4.6E-01	3.4E+00
NICKEL	1.5E+02	1.0E+03	1.5E+02			3.1E+02		5.3E+00
PENTACHLOROPHENOL	4.4E+00	5.0E+02	5.0E+00			4.4E+00		1.0E-02
PERCHLORATE	1.0E-02	1.0E+03	-			1.5E+00		1.1E+01
PHENANTHRENE	1.1E+01	5.0E+02	4.0E+01	4.4E+02	Fluorene	4.4E+02	(Use soil gas)	1.1E+01
PHENOL	7.6E-02	5.0E+02	4.0E+01			3.7E+03		7.6E-02
POLYCHLORINATED BIPHENYLS (PCBs)	2.2E-01	5.0E+02	-			2.2E-01		6.3E+00
PYRENE	8.5E+01	5.0E+02	-			3.6E+02	8.5E+01	8.5E+01
SELENIUM	1.0E+01	1.0E+03	1.0E+01			7.6E+01		
SILVER	2.0E+01	1.0E+03	2.0E+01			7.6E+01		
STYRENE	1.5E+00	5.0E+02	-			8.1E+02	4.5E+02	1.5E+00
tert-BUTYL ALCOHOL	7.3E-02	1.0E+02	-			5.7E+01	(Use soil gas)	7.3E-02
TETRACHLOROETHANE, 1,1,1,2-	2.4E-02	1.0E+02	-			3.0E+00	(Use soil gas)	2.4E-02
TETRACHLOROETHANE, 1,1,2,2-	9.1E-03	5.0E+02	-			3.7E-01	9.1E-03	1.8E-02
TETRACHLOROETHYLENE	8.7E-02	2.3E+02	-			4.3E-01	8.7E-02	7.0E-01
THALLIUM	1.0E+00	1.0E+03	-			1.0E+00		
TOLUENE	2.9E+00	5.0E+02	-			1.0E+02	1.3E+02	2.9E+00
TOXAPHENE	4.2E-04	5.0E+02	-			4.6E-01		4.2E-04
TPH (gasolines)	1.0E+02	1.0E+02	-			4.0E+02	(Use soil gas)	1.0E+02
TPH (middle distillates)	1.0E+02	1.0E+02	-			4.0E+02	(Use soil gas)	1.0E+02
TPH (residual fuels)	5.0E+02	5.0E+02	-			1.0E+03		1.0E+03
TRICHLOROBENZENE, 1,2,4-	3.8E-01	5.0E+02	3.0E+01			1.2E+01	3.8E-01	7.6E+00
TRICHLOROETHANE, 1,1,1-	7.8E+00	5.0E+02	-			3.8E+02	9.8E+01	7.8E+00
TRICHLOROETHANE, 1,1,2-	3.2E-02	1.0E+02	-			6.8E-01	3.2E-02	7.0E-02
TRICHLOROETHYLENE	2.6E-01	5.0E+02	6.0E+01			2.9E+00	2.6E-01	4.6E-01

TABLE A-1. [1]SHALLOW SOIL SCREENING LEVELS (≤3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

[2]RESIDENTIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health Substitute Direct Exposure Value	Human Health Substitute Direct Exposure Basis	Human Health Direct Exposure Table K-1	Human Health Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
TRICHLOROPHENOL, 2,4,5-	1.8E-01	1.0E+02	1.0E+01			5.0E+02	2.3E+01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	1.7E-01	5.0E+02	1.0E+01			6.9E+00		1.7E-01
VANADIUM	1.1E+02	1.0E+03	2.0E+02			1.1E+02		
VINYL CHLORIDE	6.7E-03	5.0E+02	6.0E+01			2.5E-02	6.7E-03	8.5E-02
XYLENES	2.3E+00	4.2E+02	-		m-xylenes	3.3E+02	3.1E+02	2.3E+00
ZINC	6.0E+02	1.0E+03	6.0E+02			4.6E+03		
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	-	-			-	-	
Sodium Adsorption Ratio	5.0	-	-			-	-	

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Shallow soils defined as soils situated <3 meters below ground surface.

2. "Residential Land Use" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

Final Environmental Screening Level is lowest of ceiling value (nuisance concerns etc.), ecotoxicity, direct-exposure, indoor-air impact, and leaching screening levels.
Assumes soil pH 5.0 to 9.0.
Soil data should be reported on dry-weight basis (see Section 6.2).
TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Background As and total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE A-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	Urban Area Ecotoxicity Criteria	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg) Human Health				Groundwater Protection (Soil Leaching)
				Substitute Direct Exposure Value	Basis	Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Drinking Water Resource Table G
ACENAPHTHENE	1.6E+01	2.5E+03	--			4.4E+03	1.3E+02	1.6E+01
ACENAPHTHYLENE	1.3E+01	1.0E+03	-			3.7E+03	(Use soil gas)	1.3E+01
ACETONE	5.0E-01	1.0E+03	-	3.7E+03	Fluorene	1.0E+04	3.3E+03	5.0E-01
ALDRIN	1.3E-01	2.5E+03	3.5E-01			1.3E-01		5.0E+00
ANTHRACENE	2.8E+00	1.0E+03	4.0E+01			3.1E+04	6.1E+00	2.8E+00
ANTIMONY	4.0E+01	2.5E+03	4.0E+01			7.7E+01		
ARSENIC	5.5E+00	2.5E+03	4.0E+01	5.5E+00	Background	5.5E+00		
BARIUM	1.5E+03	2.5E+03	1.5E+03			2.5E+03		
BENZENE	4.4E-02	1.0E+03	2.5E+01			3.8E-01	5.1E-01	4.4E-02
BENZO(a)ANTHRACENE	1.3E+00	1.0E+03	4.0E+01			1.3E+00		1.2E-01
BENZO(b)FLUORANTHENE	1.3E+00	1.0E+03	-			1.3E+00		4.6E+01
BENZO(k)FLUORANTHENE	1.3E+00	1.0E+03	4.0E+01			1.3E+00		2.7E+00
BENZO(g,h,i)PERYLENE	2.7E+01	1.0E+03	4.0E+01			4.4E+03		2.7E+01
BENZO(a)PYRENE	1.3E-01	1.0E+03	4.0E+01			1.3E-01		1.3E+02
BERYLLIUM	8.0E+00	2.5E+03	8.0E+00			3.6E+01		
BIPHENYL, 1,1-	6.5E-01	1.0E+03	-			3.6E+03	(Use soil gas)	6.5E-01
BIS(2-CHLOROETHYL)ETHER	1.8E-04	1.0E+03	-			2.2E-01	1.2E-02	1.8E-04
BIS(2-CHLOROISOPROPYL)ETHER	5.4E-03	7.9E+02	-			6.5E+00	(Use soil gas)	5.4E-03
BIS(2-ETHYLHEXYL)PHTHALATE	6.6E+01	1.0E+03	-			5.7E+02		6.6E+01
BORON	2.0E+00	no critiera	2.0E+00			2.5E+04		
BROMODICHLOROMETHANE	3.9E-02	2.5E+03				8.4E-01	3.9E-02	1.9E+00
BROMOFORM	2.2E+00	1.0E+03				2.2E+02		2.2E+00
BROMOMETHANE	3.9E-01	1.0E+03				2.5E+00	5.1E-01	3.9E-01
CADMIUM	7.4E+00	2.5E+03	1.2E+01			7.4E+00		
CARBON TETRACHLORIDE	3.4E-02	1.0E+03				1.9E-01	3.4E-02	1.1E-01
CHLORDANE	1.7E+00	2.5E+03				1.7E+00		1.5E+01
CHLOROANILINE, p-	5.3E-02	2.5E+03				4.9E+02		5.3E-02
CHLOROBENZENE	1.5E+00	6.8E+02	3.0E+01			1.0E+02	6.2E+00	1.5E+00
CHLOROETHANE	8.5E-01	1.0E+03				6.4E+00	1.8E+00	8.5E-01
CHLOROFORM	1.9E+00	1.0E+03				1.9E+00	3.3E-02	2.1E+00
CHLOROMETHANE	2.0E-01	5.0E+02				6.3E-01	2.0E-01	2.1E-01
CHLOROPHENOL, 2-	1.2E-02	5.0E+02	1.0E+01			4.5E+01	2.0E+00	1.2E-02
CHROMIUM (Total)	5.8E+01	2.5E+03		58	Background	5.8E+01		
CHROMIUM III	7.5E+02	2.5E+03	7.5E+02			2.9E+05		
CHROMIUM VI	1.8E+00	2.5E+03	8.0E+00			1.8E+00		
CHRYSENE	1.3E+01	2.5E+03	4.0E+01			1.3E+01		1.9E+01
COBALT	1.0E+01	2.5E+03	8.0E+01			1.0E+01		
COPPER	2.3E+02	2.5E+03	2.3E+02			7.7E+03		

TABLE A-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	Urban Area Ecotoxicity Criteria	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg) Human Health Substitute Direct Exposure Value	Basis	Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
CYANIDE (Free)	3.6E-03	5.0E+02	-			2.5E+03		3.6E-03
DIBENZO(a,h)ANTHRACENE	3.8E-01	1.0E+03	-			3.8E-01		9.9E+00
DIBROMOCHLOROMETHANE	5.4E-02	5.0E+02	-			2.2E+00	5.4E-02	8.3E+00
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	1.0E+03	-			6.7E-02	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	3.3E-04	1.0E+03	-			2.5E-01	2.0E-02	3.3E-04
DICHLOROBENZENE, 1,2-	1.1E+00	6.0E+02	3.0E+01			6.0E+02	2.1E+01	1.1E+00
DICHLOROBENZENE, 1,3-	7.4E+00	3.8E+02	3.0E+01			4.0E+02	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	1.3E-01	1.0E+03	3.0E+01			4.5E+00	1.3E-01	5.9E-01
DICHLOROBENZIDINE, 3,3-	7.7E-03	1.0E+03	-			1.4E+00		7.7E-03
DICHLORODIPHENYLDICHLOROETHANE (DDD)	9.0E+00	1.0E+03	-			9.0E+00		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	4.0E+00	1.0E+03	4.0E+00			6.3E+00		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	4.0E+00	2.5E+03	4.0E+00			6.3E+00		4.3E+00
DICHLOROETHANE, 1,1-	2.0E-01	1.0E+03	-			5.9E+00	8.9E-01	2.0E-01
DICHLOROETHANE, 1,2-	4.5E-03	1.0E+03	6.0E+01			7.4E-01	7.0E-02	4.5E-03
DICHLOROETHYLENE, 1,1-	1.0E+00	1.0E+03	-			8.1E+01	2.1E+01	1.0E+00
DICHLOROETHYLENE, Cis 1,2-	1.9E-01	5.0E+02	-			2.9E+01	3.6E+00	1.9E-01
DICHLOROETHYLENE, Trans 1,2-	6.7E-01	1.0E+03	-			4.6E+01	7.3E+00	6.7E-01
DICHLOROPHENOL, 2,4-	3.0E-01	1.0E+03	1.0E+01			3.7E+02		3.0E-01
DICHLOROPROPANE, 1,2-	1.2E-01	5.0E+02	-			1.4E+00	1.4E-01	1.2E-01
DICHLOROPROPENE, 1,3-	5.9E-02	1.0E+03	-			4.6E-01	9.3E-02	5.9E-02
DIELDRIN	2.3E-03	2.5E+03	4.0E+00			1.3E-01		2.3E-03
DIETHYLPHTHALATE	3.5E-02	1.0E+03	-			9.8E+04		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	1.0E+03	-			1.2E+06		3.5E-02
DIMETHYLPHENOL, 2,4-	6.7E-01	5.0E+02	-			7.1E+02	3.0E+02	6.7E-01
DINITROPHENOL, 2,4-	4.0E-02	1.0E+03	-			2.5E+02		4.0E-02
DINITROTOLUENE, 2,4-	8.5E-04	1.0E+03	-			5.6E+00		8.5E-04
1,4 DIOXANE	1.8E-03	1.0E+03	-			6.4E+01		1.8E-03
DIOXIN (2,3,7,8-TCDD)	1.9E-05	no criteria	-			1.9E-05		
ENDOSULFAN	4.6E-03	1.0E+03	-			7.4E+02		4.6E-03
ENDRIN	6.5E-04	1.0E+03	6.0E-02			4.6E+01		6.5E-04
ETHANOL	4.5E+01	1.0E+03	-					4.5E+01
ETHYLBENZENE	3.3E+00	4.0E+02	-			4.0E+02	3.9E+02	3.3E+00
FLUORANTHENE	4.0E+01	1.0E+03	4.0E+01			4.4E+03		6.0E+01
FLUORENE	8.9E+00	1.0E+03	-			3.7E+03	1.6E+02	8.9E+00
HEPTACHLOR	1.4E-02	2.5E+03	-			5.2E-01		1.4E-02
HEPTACHLOR EPOXIDE	1.5E-02	2.5E+03	-			3.1E-01		1.5E-02
HEXACHLOROBENZENE	9.6E-01	1.0E+03	3.0E+01			9.6E-01		7.9E+02
HEXACHLOROBUTADIENE	1.0E+00	1.0E+03	-			2.2E+01		1.0E+00

TABLE A-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	Urban Area Ecotoxicity Criteria	Substitute Direct Exposure Value	Basis	Human Health Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	1.0E+03	2.0E+00			2.0E+00		4.9E-02
HEXACHLOROETHANE	2.4E+00	1.0E+03	-			4.4E+01		2.4E+00
INDENO(1,2,3-cd)PYRENE	1.3E+00	1.0E+03	4.0E+01			1.3E+00		7.7E+00
LEAD	7.5E+02	2.5E+03	-			7.5E+02		
MERCURY	1.0E+01	1.0E+03	1.0E+01			3.7E+01	(Use soil gas)	
METHOXYCHLOR	1.9E+01	1.0E+03	-			7.7E+02		1.9E+01
METHYLENE CHLORIDE	7.7E-02	1.0E+03	-			9.2E+00	1.5E+00	7.7E-02
METHYL ETHYL KETONE	3.9E+00	1.0E+03	-			5.3E+03	1.3E+03	3.9E+00
METHYL ISOBUTYL KETONE	2.8E+00	5.0E+02	-			5.5E+02	3.1E+02	2.8E+00
METHYL MERCURY	1.0E+01	5.0E+02	1.0E+01			1.2E+01		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	2.5E+03	-			1.3E+03	1.1E+02	2.5E-01
METHYL TERT BUTYL ETHER	2.3E-02	5.0E+02	-			6.8E+01	5.6E+00	2.3E-02
MOLYBDENUM	4.0E+01	2.5E+03	4.0E+01			9.6E+02		
NAPHTHALENE	1.5E+00	1.0E+03	4.0E+01			3.8E+00	1.5E+00	3.4E+00
NICKEL	1.5E+02	2.5E+03	1.5E+02			1.0E+03		
PENTACHLOROPHENOL	5.0E+00	1.0E+03	5.0E+00			1.3E+01		5.3E+00
PERCHLORATE	1.0E-02	2.5E+03	-			1.9E+01		1.0E-02
PHENANTHRENE	1.1E+01	1.0E+03	4.0E+01	3.7E+03	Fluorene	3.7E+03	(Use soil gas)	1.1E+01
PHENOL	7.6E-02	1.0E+03	4.0E+01			3.7E+04		7.6E-02
POLYCHLORINATED BIPHENYLS (PCBs)	7.4E-01	1.0E+03	-			7.4E-01		6.3E+00
PYRENE	8.5E+01	1.0E+03	-			3.6E+03		8.5E+01
SELENIUM	1.0E+01	2.5E+03	1.0E+01			9.6E+02	8.5E-01	
SILVER	4.0E+01	2.5E+03	4.0E+01			9.6E+02		
STYRENE	1.5E+00	1.0E+03	-			1.5E+03	1.1E+03	1.5E+00
tert-BUTYL ALCOHOL	7.3E-02	5.0E+02	-			1.5E+02	(Use soil gas)	7.3E-02
TETRACHLOROETHANE, 1,1,1,2-	2.4E-02	5.0E+02	-			6.9E+00	(Use soil gas)	2.4E-02
TETRACHLOROETHANE, 1,1,2,2-	1.8E-02	1.0E+03	-			8.6E-01	2.5E-02	1.8E-02
TETRACHLOROETHYLENE	2.4E-01	2.3E+02	-			1.1E+00	2.4E-01	7.0E-01
THALLIUM	1.3E+01	2.5E+03	-			1.3E+01		
TOLUENE	2.9E+00	6.5E+02	-			3.4E+02	3.1E+02	2.9E+00
TOXAPHENE	4.2E-04	1.0E+03	-			1.8E+00		4.2E-04
TPH (gasolines)	1.0E+02	5.0E+02	-			7.5E+02	(Use soil gas)	1.0E+02
TPH (middle distillates)	1.0E+02	5.0E+02	-			7.5E+02	(Use soil gas)	1.0E+02
TPH (residual fuels)	1.0E+03	2.5E+03	-			4.6E+03		1.0E+03
TRICHLOROBENZENE, 1,2,4-	1.0E+00	1.0E+03	3.0E+01			4.2E+01	1.0E+00	7.6E+00
TRICHLOROETHANE, 1,1,1-	7.8E+00	1.0E+03	-			1.2E+03	2.3E+02	7.8E+00
TRICHLOROETHANE, 1,1,2-	7.0E-02	5.0E+02	-			1.5E+00	8.9E-02	7.0E-02
TRICHLOROETHYLENE	4.6E-01	1.3E+03	6.0E+01			6.3E+00	7.3E-01	4.6E-01

TABLE A-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	Urban Area Ecotoxicity Criteria	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg) Human Health Substitute Direct Exposure Value	Basis	Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
TRICHLOROPHENOL, 2,4,5-	1.8E-01	5.0E+02	1.0E+01			2.2E+03	6.1E+01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	1.7E-01	1.0E+03	1.0E+01			2.5E+01		1.7E-01
VANADIUM	2.0E+02	2.5E+03	2.0E+02			1.3E+03		
VINYL CHLORIDE	1.9E-02	1.0E+03	6.0E+01			5.4E-02	1.9E-02	8.5E-02
XYLENES	2.3E+00	4.2E+02	-			4.2E+02	4.2E+02	2.3E+00
ZINC	6.0E+02	2.5E+03	6.0E+02			5.8E+04		
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	4.0	-	-			-	-	-
Sodium Adsorption Ratio	12	-	-			-	-	-

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Shallow soils defined as soils situated <3 meters below ground surface.

Final Environmental Screening Level is lowest of ceiling value (nuisance concerns etc.), ecotoxicity, direct-exposure, indoor-air impact, and leaching screening levels. Assumes soil pH 5.0 to 9.0.

Soil data should be reported on dry-weight basis (see Section 6.2).

TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

Background As and total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE B-1. [1]SHALLOW SOIL SCREENING LEVELS (<3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

[2]RESIDENTIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health					Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
				Substitute Direct Exposure		Direct Exposure Table K-1	Vapor Intrusion Into Buildings Table E-1b		
				Value	Basis				
ACENAPHTHENE	1.9E+01	1.0E+03	-			6.0E+02	1.3E+02		1.9E+01
ACENAPHTHYLENE	1.3E+01	5.0E+02	-	4.4E+02	Fluorene	4.4E+02	(Use soil gas)		1.3E+01
ACETONE	5.0E-01	5.0E+02	-			2.7E+03	1.4E+03		5.0E-01
ALDRIN	3.2E-02	1.0E+03	3.5E-01			3.2E-02			5.0E+00
ANTHRACENE	2.8E+00	5.0E+02	4.0E+01			3.5E+03	6.1E+00		5.0E+00
ANTIMONY	6.1E+00	1.0E+03	2.0E+01			6.1E+00			2.8E+00
ARSENIC	5.5E+00	1.0E+03	2.0E+01	5.5E+00	Background	5.5E+00			
BARIUM	7.5E+02	1.0E+03	7.5E+02			1.0E+03			
BENZENE	1.8E-01	5.0E+02	2.5E+01			1.8E-01	1.8E-01		2.0E+00
BENZO(a)ANTHRACENE	3.8E-01	5.0E+02	4.0E+01			3.8E-01			1.2E+01
BENZO(b)FLUORANTHENE	3.8E-01	5.0E+02				3.8E-01			4.6E+01
BENZO(k)FLUORANTHENE	3.8E-01	5.0E+02	4.0E+01			3.8E-01			3.7E+01
BENZO(g,h,i)PERYLENE	2.7E-01	5.0E+02	4.0E+01			4.6E+02			2.7E+01
BENZO(a)PYRENE	3.8E-02	5.0E+02	4.0E+01			3.8E-02			1.3E+02
BERYLLIUM	4.0E+00	1.0E+03	4.0E+00			2.9E+01			
BIPHENYL, 1,1-	6.5E+00	5.0E+02	-			4.9E+02	(Use soil gas)		6.5E+00
BIS(2-CHLOROETHYL)ETHER	3.7E-03	5.0E+02	-			8.5E-02	3.7E-03		7.8E-01
BIS(2-CHLOROISOPROPYL)ETHER	6.6E-01	5.0E+02	-			2.6E+00	(Use soil gas)		6.6E-01
BIS(2-ETHYLHEXYL)PHTHALATE	1.6E+02	5.0E+02				1.6E+02			5.3E+02
BORON	1.6E+00	no criteria	1.6E+00			2.4E+03			
BROMODICHLOROMETHANE	1.4E-02	1.0E+03				3.8E-01	1.4E-02		3.2E+00
BROMOFORM	6.1E-01	5.0E+02	-			6.1E+01			6.9E+01
BROMOMETHANE	2.2E-01	5.0E+02	-			7.5E-01	2.2E-01		6.4E+00
CADMIUM	1.7E+00	1.0E+03	1.2E+01			1.7E+00			
CARBON TETRACHLORIDE	1.2E-02	5.0E+02	-			8.9E+02	1.2E+00		2.0E+00
CHLORDANE	4.4E-01	1.0E+03	-			4.4E-01			1.5E-01
CHLOROANILINE, p-	5.3E-02	1.0E+03	-			4.9E+01			5.3E-02
CHLOROBENZENE	1.5E+00	5.0E+02	3.0E+01			2.9E+01	2.7E+00		1.5E+00
CHLOROETHANE	6.3E-01	5.0E+02	-			3.0E+00	6.3E-01		8.5E-01
CHLOROFORM	8.8E-01	5.0E+02	-			8.8E-01	1.4E+02		9.8E+00
CHLOROMETHANE	7.0E-02	1.0E+02	-			3.0E-01	7.0E-02		6.4E+00
CHLOROPHENOL, 2-	1.2E-01	1.0E+02	1.0E+01			1.2E-01	7.8E-01		1.2E-01
CHROMIUM (Total)	5.8E+01	1.0E+03		58	Background	5.8E+01			
CHROMIUM III	7.5E+02	1.0E+03	7.5E+02			2.3E+04			
CHROMIUM VI	1.8E+00	1.0E+03	8.0E+00			1.8E+00			
CHRYSENE	3.8E+00	1.0E+03	4.0E+01			3.8E+00			2.3E+01
COBALT	1.0E+01	1.0E+03	4.0E+01			1.0E+01			
COPPER	2.3E+02	1.0E+03	2.3E+02			6.1E+02			

TABLE B-1. [1]SHALLOW SOIL SCREENING LEVELS (<3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

[2]RESIDENTIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health — Substitute Direct Exposure Value	Human Health — Substitute Direct Exposure Basis	Human Health — Direct Exposure Table K-1	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
CYANIDE (Free)	3.6E-03	1.0E+02	-			2.4E+02		3.6E-03
DIBENZO(a,h)ANTHTRACENE	1.1E-01	5.0E+02	-			1.1E-01		1.4E+02
DIBROMOCHLOROMETHANE	1.9E-02	1.0E+02	-			9.4E-01	1.9E-02	1.4E+01
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	5.0E+02	-			2.7E-02	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	7.3E-03	5.0E+02	-			8.7E-02	7.3E-03	1.0E+00
DICHLOROBENZENE, 1,2-	1.6E+00	6.0E+02	3.0E+01			2.1E+02	8.9E+00	1.6E+00
DICHLOROBENZENE, 1,3-	7.4E+00	1.0E+02	3.0E+01			9.9E+01	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	4.6E-02	5.0E+02	3.0E+01			2.1E+00	4.6E-02	1.8E+00
DICHLOROBENZIDINE, 3,3-	4.0E-01	5.0E+02	-			4.0E-01		6.6E+01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.3E+00	5.0E+02	-			2.3E+00		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.6E+00	5.0E+02	4.0E+00			1.6E+00		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.6E+00	1.0E+03	4.0E+00			1.6E+00		4.3E+00
DICHLOROETHANE, 1,1-	3.2E-01	5.0E+02	-			2.7E+00	3.2E-01	1.9E+00
DICHLOROETHANE, 1,2-	2.5E-02	5.0E+02	6.0E+01			3.4E-01	2.5E-02	1.8E+00
DICHLOROETHYLENE, 1,1-	4.3E+00	5.0E+02	-			2.4E+01	8.9E+00	4.3E+00
DICHLOROETHYLENE, Cis 1,2-	1.6E+00	1.0E+02	-			8.4E+00	1.6E+00	1.8E+01
DICHLOROETHYLENE, Trans 1,2-	3.1E+00	5.0E+02	-			1.4E+01	3.1E+00	3.9E+01
DICHLOROPHENOL, 2,4-	3.0E+00	5.0E+02	1.0E+01			3.7E+01		3.0E+00
DICHLOROPROPANE, 1,2-	5.1E-02	1.0E+02	-			6.3E-01	5.1E-02	2.5E+00
DICHLOROPROPENE, 1,3-	3.3E-02	5.0E+02	-			2.1E-01	3.3E-02	6.2E+00
DIELDRIN	2.3E-03	1.0E+03	4.0E+00			3.4E-02		2.3E-03
DIETHYLPHTHALATE	3.5E-02	5.0E+02	-			9.8E-03		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	5.0E+02	-			1.2E+05		3.5E-02
DIMETHYLPHENOL, 2,4-	7.4E-01	1.0E+02	-			1.4E+02	1.1E+02	7.4E-01
DINITROPHENOL, 2,4-	2.1E-01	5.0E+02	-			2.4E+01		2.1E-01
DINITROTOLUENE, 2,4-	8.6E-01	5.0E+02	-			1.6E+00		8.6E-01
1,4 DIOXANE	1.8E+01	5.0E+02	-			1.8E+01		3.0E+01
DIOXIN (2,3,7,8-TCDD)	4.6E-06	no criteria	-			4.6E-06		
ENDOSULFAN	4.6E-03	5.0E+02	-			7.3E+01		4.6E-03
ENDRIN	6.5E-04	5.0E+02	6.0E-02			4.1E+00		6.5E-04
ETHANOL	4.5E+01	5.0E+02	-					4.5E+01
ETHYLBENZENE	3.2E+01	4.0E+02	-			4.0E+02	3.9E+02	3.2E+01
FLUORANTHENE	4.0E+01	5.0E+02	4.0E+01			4.6E+02		6.0E+01
FLUORENE	8.9E+00	5.0E+02	-			4.4E+02	1.6E+02	8.9E+00
HEPTACHLOR	1.4E-02	1.0E+03	-			1.3E-01		1.4E-02
HEPTACHLOR EPOXIDE	1.5E-02	1.0E+03	-			8.8E-02		1.5E-02
HEXACHLOROBENZENE	2.7E-01	5.0E+02	3.0E+01			2.7E-01		7.9E+02
HEXACHLOROBUTADIENE	3.7E+00	5.0E+02	-			3.7E+00		2.3E+01

TABLE B-1. [1]SHALLOW SOIL SCREENING LEVELS (<3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	[2]RESIDENTIAL LAND USE (mg/kg) Human Health — Substitute Direct Exposure Value	Basis	Direct Exposure Table K-1	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	5.0E+02	2.0E+00			5.0E-01		4.9E-02
HEXACHLOROETHANE	1.2E+01	5.0E+02				1.2E+01		4.1E+01
INDENO(1,2,3-cd)PYRENE	3.8E-01	5.0E+02	4.0E+01			3.8E-01		
LEAD	1.5E+02	1.0E+03	2.0E+02			1.50E+02		7.7E+00
MERCURY	3.7E+00	5.0E+02	1.0E+01			3.7E+00	(Use soil gas)	
METHOXYCHLOR	1.9E+01	5.0E+02	-			6.9E+01		1.9E+01
METHYLENE CHLORIDE	5.2E-01	5.0E+02	-			4.1E+00	5.2E-01	3.4E+01
METHYL ETHYL KETONE	1.3E+01	5.0E+02	-			1.4E+03	4.9E+02	1.3E+01
METHYL ISOBUTYL KETONE	3.9E+00	1.0E+02	-			1.5E+02	1.2E+02	3.9E+00
METHYL MERCURY	1.2E+00	1.0E+02	1.0E+01			1.2E+00		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	5.0E+02	-			2.6E+02	1.1E+02	2.5E-01
METHYL TERT BUTYL ETHER	2.0E+00	1.0E+02	-			3.0E+01	2.0E+00	8.4E+00
MOLYBDENUM	4.0E+01	1.0E+03	4.0E+01			7.6E+01		
NAPHTHALENE	4.6E-01	5.0E+02	4.0E+01			1.5E+00	4.6E-01	4.8E+00
NICKEL	1.5E+02	1.0E+03	1.5E+02			3.1E+02		
PENTACHLOROPHENOL	4.4E+00	5.0E+02	5.0E+00			4.4E+00		4.2E+01
PERCHLORATE	1.2E+00	1.0E+03	-			1.5E+00		1.2E+00
PHENANTHRENE	1.1E+01	5.0E+02	4.0E+01	4.4E+02	Fluorene		(Use soil gas)	1.1E+01
PHENOL	1.9E+01	5.0E+02	4.0E+01			3.7E+03		1.9E+01
POLYCHLORINATED BIPHENYLS (PCBs)	2.2E-01	5.0E+02	-			2.2E-01		6.3E+00
PYRENE	8.5E+01	5.0E+02	-			3.6E+02	8.5E+01	8.5E+01
SELENIUM	1.0E+01	1.0E+03	1.0E+01			7.6E+01		
SILVER	2.0E+01	1.0E+03	2.0E+01			7.6E+01		
STYRENE	1.5E+01	5.0E+02	-			8.1E+02	4.5E+02	1.5E+01
tert-BUTYL ALCOHOL	5.7E+01	1.0E+02	-			5.7E+01	(Use soil gas)	1.1E+02
TETRACHLOROETHANE, 1,1,1,2-	3.0E+00	1.0E+02	-			3.0E+00	(Use soil gas)	1.6E+01
TETRACHLOROETHANE, 1,1,2,2-	9.1E-03	5.0E+02	-			3.7E-01	9.1E-03	3.4E+00
TETRACHLOROETHYLENE	8.7E-02	2.3E+02	-			4.3E-01	8.7E-02	1.7E+01
THALLIUM	1.0E+00	1.0E+03	-			1.0E+00		
TOLUENE	9.3E+00	5.0E+02	-			1.0E+02	1.3E+02	9.3E+00
TOXAPHENE	4.2E-04	5.0E+02	-			4.6E-01		4.2E-04
TPH (gasolines)	1.0E+02	5.0E+02	-			4.0E+02	(Use soil gas)	4.0E+02
TPH (middle distillates)	1.0E+02	1.0E+02	-			4.0E+02	(Use soil gas)	5.0E+02
TPH (residual fuels)	5.0E+02	5.0E+02	-			1.0E+03		1.0E+03
TRICHLOROBENZENE, 1,2,4-	3.8E-01	5.0E+02	3.0E+01			1.2E+01	3.8E-01	7.6E+00
TRICHLOROETHANE, 1,1,1-	7.8E+00	5.0E+02	-			3.8E+02	9.8E+01	7.8E+00
TRICHLOROETHANE, 1,1,2-	3.2E-02	1.0E+02	-			6.8E-01	3.2E-02	4.8E+00
TRICHLOROETHYLENE	2.6E-01	5.0E+02	6.0E+01			2.9E+00	2.6E-01	3.3E-01

Table B-1 (Shallow, NDW, Res)

TABLE B-1. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
²RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

⁴RESIDENTIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health Substitute Direct Exposure Value	Human Health Substitute Direct Exposure Basis	Human Health Direct Exposure Table K-1	Human Health Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
TRICHLOROPHENOL, 2,4,5-	1.8E-01	1.0E+02	1.0E+01			5.0E+02	2.3E+01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	6.9E+00	5.0E+02	1.0E+01			6.9E+00		1.6E+02
VANADIUM	1.1E+02	1.0E+03	2.0E+02			1.1E+02		
VINYL CHLORIDE	6.7E-03	5.0E+02	6.0E+01			2.5E-02	6.7E-03	6.6E-01
XYLENES	1.1E+01	4.2E+02	-		m-xylene RfDs	3.3E+02	3.1E+02	1.1E+01
ZINC	6.0E+02	1.0E+03	6.0E+02			4.6E+03		
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	-	-			-	-	-
Sodium Adsorption Ratio	5.0	-	-			-	-	-

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Shallow soils defined as soils situated <3 meters below ground surface.

2. Sensitive land use based on residential land-use and exposure scenarios (see Chapter 1).

Final Environmental Screening Level is lowest of ceiling value (nuisance concerns etc.), ecotoxicity, direct-exposure, indoor-air impact, and leaching screening levels.
Assumes soil pH 5.0 to 9.0.
Soil data should be reported on dry-weight basis (see Section 6.2).
TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Background As and total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE B-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health — Substitute Direct Exposure — Value	Human Health — Substitute Direct Exposure — Basis	Human Health — Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
ACENAPHTHENE	1.9E+01	2.5E+03	-			4.4E+03	1.3E+02	1.9E+01
ACENAPHTHYLENE	1.3E+01	1.0E+03	-	3.7E+03	Fluorene	3.7E+03	(Use soil gas)	1.3E+01
ACETONE	5.0E-01	1.0E+03	-			1.0E+04	3.3E+03	5.0E-01
ALDRIN	1.3E-01	2.5E+03	3.5E-01			1.3E-01		5.0E+00
ANTHRACENE	2.8E+00	1.0E+03	4.0E+01			3.1E+04	6.1E+00	2.8E+00
ANTIMONY	4.0E+01	2.5E+03	4.0E+01			7.7E+01		
ARSENIC	5.5E+00	2.5E+03	4.0E+01	5.5E+00	Background	5.5E+00		
BARIUM	1.5E+03	2.5E+03	1.5E+03			5.5E+03		
BENZENE	3.8E-01	1.0E+03	2.5E+01			2.5E+03	5.1E-01	2.0E+00
BENZO(a)ANTHRACENE	1.3E+00	1.0E+03	4.0E+01			3.8E-01		1.2E+01
BENZO(b)FLUORANTHENE	1.3E+00	1.0E+03	-			1.3E+00		4.6E+01
BENZO(k)FLUORANTHENE	1.3E+00	1.0E+03	4.0E+01			1.3E+00		3.7E+01
BENZO(g,h,i)PERYLENE	2.7E+01	1.0E+03	4.0E+01			4.4E+03		2.7E+01
BENZO(a)PYRENE	1.3E-01	1.0E+03	4.0E+01			1.3E-01		1.3E+02
BERYLLIUM	8.0E+00	2.5E+03	8.0E+00			3.6E+01		
BIPHENYL, 1,1-	6.5E+00	1.0E+03	-			3.6E+03	(Use soil gas)	6.5E+00
BIS(2-CHLOROETHYL)ETHER	1.2E-02	1.0E+03	-			2.2E-01	1.2E-02	7.8E-01
BIS(2-CHLOROISOPROPYL)ETHER	6.6E-01	7.9E+02	-			6.5E+00	(Use soil gas)	6.6E-01
BIS(2-ETHYLHEXYL)PHTHALATE	5.3E+02	1.0E+03	-			5.7E+02		5.3E+02
BORON	2.0E+00	no critiera	2.0E+00			2.5E+04		
BROMODICHLOROMETHANE	3.9E-02	2.5E+03	-			8.4E-01	3.9E-02	3.2E+00
BROMOFORM	6.9E+01	1.0E+03	-			2.2E+02		6.9E+01
BROMOMETHANE	5.1E-01	1.0E+03	-			2.5E+00	5.1E-01	6.4E+00
CADMIUM	7.4E+00	1.0E+03	1.2E+01			7.4E+00		
CARBON TETRACHLORIDE	3.4E-02	2.5E+03	-			1.9E-01	3.4E-02	2.0E+00
CHLORDANE	1.7E+00	1.0E+03	-			1.7E+00		1.5E+01
CHLOROANILINE, p-	5.3E-02	2.5E+03	-			4.9E+02		5.3E-02
CHLOROBENZENE	1.5E+00	6.8E+02	3.0E+01			1.0E+02	6.2E+00	1.5E+00
CHLOROETHANE	8.5E-01	1.0E+03	-			6.4E+00	1.8E+00	8.5E-01
CHLOROFORM	1.9E+00	1.0E+03	-			1.9E+00	3.3E+02	9.8E+00
CHLOROMETHANE	2.0E-01	5.0E+02	-			6.3E-01	2.0E-01	6.4E+00
CHLOROPHENOL, 2-	1.2E-01	5.0E+02	1.0E+01			4.5E+01	2.0E+00	1.2E-01
CHROMIUM (Total)	5.8E+01	2.5E+03		58	Background	5.8E+01		
CHROMIUM III	7.5E+02	2.5E+03	7.5E+02			2.9E+05		
CHROMIUM VI	1.8E+00	2.5E+03	8.0E+00			1.8E+00		
CHRYSENE	1.3E+01	2.5E+03	4.0E+01			1.3E+01		2.3E+01
COBALT	1.0E+01	2.5E+03	8.0E+01			1.0E+01		
COPPER	2.3E+02	2.5E+03	2.3E+02			7.7E+03		

Table B-2 (Shallow, NDW, CI)

TABLE B-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Substitute Direct Exposure Value	Substitute Direct Exposure Basis	Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
CYANIDE (Free)	3.6E-03	5.0E+02	-			2.5E+03		3.6E-03
DIBENZO(a,h)ANTHTRACENE	3.8E-01	1.0E+03	-			3.8E-01		1.4E+02
DIBROMOCHLOROMETHANE	5.4E-02	5.0E+02	-			2.2E+00	5.4E-02	1.4E+01
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	1.0E+03	-			6.7E-02	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	2.0E-02	1.0E+03	-			2.5E-01	2.0E-02	1.0E+00
DICHLOROBENZENE, 1,2-	1.6E+00	6.0E+02	3.0E+01			6.0E+02	2.1E+01	1.6E+00
DICHLOROBENZENE, 1,3-	7.4E+00	3.8E+02	3.0E+01			4.0E+02	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	1.3E-01	1.0E+03	3.0E+01			4.5E+00	1.3E-01	1.8E+00
DICHLOROBENZIDINE, 3,3-	1.4E+00	1.0E+03	-			1.4E+00		6.6E+01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	9.0E+00	1.0E+03	-			9.0E+00		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	4.0E+00	1.0E+03	4.0E+00			6.3E+00		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	4.0E+00	2.5E+03	4.0E+00			6.3E+00		4.3E+00
DICHLOROETHANE, 1,1-	8.9E-01	1.0E+03	-			5.9E+00	8.9E-01	1.9E+00
DICHLOROETHANE, 1,2-	7.0E-02	1.0E+03	6.0E+01			7.4E-01	7.0E-02	1.8E+00
DICHLOROETHYLENE, 1,1-	4.3E+00	1.0E+03	-			8.1E+01	2.1E+01	4.3E+00
DICHLOROETHYLENE, Cis 1,2-	3.6E+00	5.0E+02	-			2.9E+01	3.6E+00	1.8E+01
DICHLOROETHYLENE, Trans 1,2-	7.3E+00	1.0E+03	-			4.6E+01	7.3E+00	3.9E+01
DICHLOROPHENOL, 2,4-	3.0E+00	1.0E+03	1.0E+01			3.7E+02		3.0E+00
DICHLOROPROPANE, 1,2-	1.4E-01	5.0E+02	-			1.4E+00	1.4E-01	2.5E+00
DICHLOROPROPENE, 1,3-	9.3E-02	1.0E+03	-			4.6E-01	9.3E-02	6.2E+00
DIELDRIN	2.3E-03	2.5E+03	4.0E+00			1.3E-01		2.3E-03
DIETHYLPHTHALATE	3.5E-02	1.0E+03	-			9.8E+04		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	1.0E+03	-			1.2E+06		3.5E-02
DIMETHYLPHENOL, 2,4-	7.4E-01	5.0E+02	-			7.1E+02	3.0E+02	7.4E-01
DINITROPHENOL, 2,4-	2.1E-01	1.0E+03	-			2.5E+02		2.1E-01
DINITROTOLUENE, 2,4-	8.6E-01	1.0E+03	-			5.6E+00		8.6E-01
1,4-DIOXANE	3.0E+01	1.0E+03	-			6.4E+01		3.0E+01
DIOXIN (2,3,7,8-TCDD)	1.9E-05	no criteria	-			1.9E-05		
ENDOSULFAN	4.6E-03	1.0E+03	-			7.4E+02		4.6E-03
ENDRIN	6.5E-04	1.0E+03	6.0E-02			4.6E+01		6.5E-04
ETHANOL	4.5E+01	1.0E+03	-					4.5E+01
ETHYLBENZENE	3.2E-01	4.0E+02	-			4.0E+02	3.9E+02	3.2E+01
FLUORANTHENE	4.0E+01	1.0E+03	4.0E+01			4.4E+03		6.0E+01
FLUORENE	8.9E+00	1.0E+03	-			3.7E+03	1.6E+02	8.9E+00
HEPTACHLOR	1.4E-02	2.5E+03	-			5.2E-01		1.4E-01
HEPTACHLOR EPOXIDE	1.5E-02	2.5E+03	-			3.1E-01		1.5E-02
HEXACHLOROBENZENE	9.6E-01	1.0E+03	3.0E+01			9.6E-01		7.9E+02
HEXACHLOROBUTADIENE	2.2E+01	1.0E+03	-			2.2E+01		2.3E+01

TABLE B-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health — Substitute Direct Exposure — Value	Basis	Human Health — Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	1.0E+03	2.0E+00			2.0E+00		4.9E-02
HEXACHLOROETHANE	4.1E+01	1.0E+03	-			4.4E+01		4.1E+01
INDENO(1,2,3-cd)PYRENE	1.3E+00	1.0E+03	4.0E+01			1.3E+00		7.7E+00
LEAD	7.5E+02	2.5E+03	-			7.5E+02		
MERCURY	1.0E+01	1.0E+03	1.0E+01			3.7E+01	(Use soil gas)	
METHOXYCHLOR	1.9E+01	1.0E+03	-			7.7E+02		1.9E+01
METHYLENE CHLORIDE	1.5E+00	1.0E+03	-			9.2E+00	1.5E+00	3.4E+01
METHYL ETHYL KETONE	1.3E+01	1.0E+03	-			5.3E+03	1.3E+03	1.3E+01
METHYL ISOBUTYL KETONE	3.9E+00	5.0E+02	-			5.5E+02	3.1E+02	3.9E+00
METHYL MERCURY	1.0E+01	5.0E+02	1.0E+01			1.2E+01		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	1.0E+03	-			1.3E+03	1.1E+02	2.5E-01
METHYL TERT BUTYL ETHER	5.6E+00	5.0E+02	-			6.8E+01	5.6E+00	8.4E+00
MOLYBDENUM	4.0E+01	2.5E+03	4.0E+01			9.6E+02		
NAPHTHALENE	1.5E+00	1.0E+03	4.0E+01			3.8E+00	1.5E+00	4.8E+00
NICKEL	1.5E+02	2.5E+03	1.5E+02			1.0E+03		
PENTACHLOROPHENOL	5.0E+00	1.0E+03	5.0E+00			1.3E+01		4.2E+01
PERCHLORATE	1.2E+00	2.5E+03	-			1.9E+01		1.2E+00
PHENANTHRENE	1.1E+01	1.0E+03	4.0E+01	3.7E+03	Fluorene	3.7E+03		1.1E-01
PHENOL	1.9E+01	1.0E+03	4.0E+01			3.7E+04	(Use soil gas)	1.9E+01
POLYCHLORINATED BIPHENYLS (PCBs)	7.4E-01	1.0E+03	-			7.4E-01		6.3E+00
PYRENE	8.5E+01	1.0E+03	-			3.6E+03	8.5E+01	8.5E+01
SELENIUM	1.0E+01	2.5E+03	1.0E+01			9.6E+02		
SILVER	4.0E+01	2.5E+03	4.0E+01			9.6E+02		
STYRENE	1.5E+01	1.0E+03	-			1.5E+03	1.1E+03	1.5E+01
tert-BUTYL ALCOHOL	1.1E+02	5.0E+02	-			1.5E+02	(Use soil gas)	1.1E+02
TETRACHLOROETHANE, 1,1,1,2-	6.9E+00	5.0E+02	-			6.9E+00	(Use soil gas)	1.6E+01
TETRACHLOROETHANE, 1,1,2,2-	2.5E-02	1.0E+03	-			8.6E-01	2.5E-02	3.4E+00
TETRACHLOROETHYLENE	2.4E-01	2.3E+02	-			1.1E+00	2.4E-01	1.7E+01
THALLIUM	1.3E+01	2.5E+03	-			1.3E+01		
TOLUENE	9.3E+00	6.5E+02	-			3.4E+02	3.1E+02	9.3E+00
TOXAPHENE	4.2E-04	1.0E+03	-			1.8E+00		4.2E-04
TPH (gasolines)	4.0E+02	5.0E+02	-			7.5E+02	(Use soil gas)	4.0E+02
TPH (middle distillates)	5.0E+02	5.0E+02	-			7.5E+02	(Use soil gas)	5.0E+02
TPH (residual fuels)	1.0E+03	2.5E+03	-			4.6E+03		1.0E+03
TRICHLOROBENZENE, 1,2,4-	1.0E+00	1.0E+03	3.0E+01			4.2E+01	1.0E+00	7.6E+00
TRICHLOROETHANE, 1,1,1-	7.8E+00	1.0E+03	-			1.2E+03	2.3E+02	7.8E+00
TRICHLOROETHANE, 1,1,2-	8.9E-02	5.0E+02	-			1.5E+00	8.9E-02	4.8E+00
TRICHLOROETHYLENE	7.3E-01	1.3E+03	6.0E+01			6.3E+00	7.3E-01	3.3E+01

TABLE B-2. ¹SHALLOW SOIL SCREENING LEVELS (<3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-2	Urban Area Ecotoxicity Criteria	Human Health Substitute Direct Exposure Value	Substitute Direct Exposure Basis	Direct Exposure Table K-2	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
TRICHLOROPHENOL, 2,4,5-	1.8E-01	5.0E+02	1.0E+01			2.2E+03	6.1E+01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	1.0E+01	1.0E+03	1.0E+01			2.5E+01		1.6E+02
VANADIUM	2.0E+02	2.5E+03	2.0E+02			1.3E+03		
VINYL CHLORIDE	1.9E-02	1.0E+03	6.0E+01			5.4E-02	1.9E-02	6.6E-01
XYLENES	1.1E+01	4.2E+02	-			4.2E+02	4.2E+02	1.1E+01
ZINC	6.0E+02	2.5E+03	6.0E+02			5.8E+04		
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	4.0	-	-			-	-	-
Sodium Adsorption Ratio	12	-	-			-	-	-

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Shallow soils defined as soils situated <3 meters below ground surface.

Final Environmental Screening Level is lowest of ceiling value (nuisance concerns etc.), ecotoxicity, direct-exposure, indoor-air impact, and leaching screening levels.
Assumes soil pH 5.0 to 9.0.
Soil data should be reported on dry-weight basis (see Section 6.2).
TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Background As and total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE C-1. [1]DEEP SOIL SCREENING LEVELS (>3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	[2]RESIDENTIAL LAND USE (mg/kg)				
			Substitute Direct Exposure		Human Health		Groundwater Protection (Soil Leaching)
			Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Drinking Water Resource Table G
ACENAPHTHENE	1.6E+01	2.5E+03			2.1E+04	1.3E+02	1.6E+01
ACENAPHTHYLENE	1.3E+01	1.0E+03			1.5E+04	(Use soil gas)	1.3E+01
ACETONE	5.0E-01	1.0E+03	1.5E+04	Fluorene	1.0E+05	1.4E+03	5.0E-01
ALDRIN	1.5E+00	2.5E+03			1.5E+00		5.0E+00
ANTHRACENE	2.8E+00	1.0E+03			1.2E+05	6.1E+00	5.0E+00
ANTIMONY	2.8E+02	2.5E+03			2.8E+02		2.8E+00
ARSENIC	5.5E+00	2.5E+03	5.5E+00	Background	5.5E+00		
BARIUM	2.5E+03	2.5E+03			2.5E+03		
BENZENE	4.4E-02	1.0E+03			1.6E+01	1.8E-01	4.4E-02
BENZO(a)ANTHRACENE	1.2E+01	1.0E+03			1.5E+01		1.2E+01
BENZO(b)FLUORANTHENE	1.5E+01	1.0E+03			1.5E+01		4.6E+01
BENZO(k)FLUORANTHENE	2.7E+00	1.0E+03			1.5E+01		2.7E+00
BENZO(g,h,i)PERYLENE	2.7E+01	1.0E+03			1.4E+04		2.7E+01
BENZO(a)PYRENE	1.5E+00	1.0E+03			1.5E+00		1.3E+02
BERYLLIUM	3.6E+01	2.5E+03			3.6E+01		
BIPHENYL, 1,1-	6.5E-01	1.0E+03			1.7E+04	(Use soil gas)	6.5E-01
BIS(2-CHLOROETHYL)ETHER	1.8E-04	1.0E+03			5.2E+00	3.7E-03	1.8E-04
BIS(2-CHLOROISOPROPYL)ETHER	5.4E-03	7.9E+02			1.7E+02	(Use soil gas)	5.4E-03
BIS(2-ETHYLHEXYL)PHTHALATE	6.6E+01	1.0E+03			6.4E+03		6.6E+01
BORON	4.6E+04	no criteria			4.6E+04		
BROMODICHLOROMETHANE	1.4E-02	2.5E+03			3.2E+01	1.4E-02	1.9E+00
BROMOFORM	2.2E+00	1.0E+03			2.6E+03		2.2E+00
BROMOMETHANE	2.2E-01	1.0E+03			3.0E+01	2.2E-01	3.9E-01
CADMIUM	3.8E+01	2.5E+03			3.8E+01		
CARBON TETRACHLORIDE	1.2E-02	1.0E+03			8.2E+00	1.2E-02	1.1E-01
CHLORDANE	1.5E+01	2.5E+03			2.1E+01		1.5E+01
CHLOROANILINE, p-	5.3E-02	2.5E+03			1.6E+03		5.3E-02
CHLOROBENZENE	1.5E+00	6.8E+02			6.8E+02	2.7E+00	1.5E+00
CHLOROETHANE	6.3E-01	1.0E+03			2.8E+02	6.3E-01	8.5E-01
CHLOROFORM	2.1E+00	1.0E+03			7.8E+01	1.4E-02	2.1E+00
CHLOROMETHANE	7.0E-02	5.0E+02			2.8E+01	7.0E-02	2.1E-01
CHLOROPHENOL, 2-	1.2E-02	5.0E+02			4.7E+02	7.8E-01	1.2E-02
CHROMIUM (Total)	5.8E+01	2.5E+03	58	Background	5.8E+01		
CHROMIUM III	2.5E+03	2.5E+03			1.1E+06		
CHROMIUM VI	1.8E+00	2.5E+03			1.8E+00		
CHRYSENE	1.9E+01	2.5E+03			1.5E+02		1.9E+01
COBALT	1.0E+01	2.5E+03			1.0E+01		
COPPER	2.5E+03	2.5E+03			2.8E+04		

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
CYANIDE (Free)	3.6E-03	5.0E+02			8.2E+03		3.6E-03
DIBENZO(a,h)ANTHTRACENE	4.3E+00	1.0E+03			4.3E+00		9.9E+00
DIBROMOCHLOROMETHANE	1.9E-02	5.0E+02			7.3E+01	1.9E-02	8.3E+00
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	1.0E+03			1.7E+00	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	3.3E-04	1.0E+03			4.6E+00	7.3E-03	3.3E-04
DICHLOROBENZENE, 1,2-	1.1E+00	6.0E+02			6.0E+02	8.9E+00	1.1E+00
DICHLOROBENZENE, 1,3-	7.4E+00	6.0E+02			6.0E+02	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	4.6E-02	1.0E+03			1.9E+02	4.6E-02	5.9E-01
DICHLOROBENZIDINE, 3,3-	7.7E-03	1.0E+03			1.7E+01		7.7E-03
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.1E+02	1.0E+03			1.1E+02		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	7.6E+01	1.0E+03			7.6E+01		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	4.3E+00	2.5E+03			7.6E+01		4.3E+00
DICHLOROETHANE, 1,1-	2.0E-01	1.0E+03			2.5E+02	3.2E-01	2.0E-01
DICHLOROETHANE, 1,2-	4.5E-03	1.0E+03			3.1E+01	2.5E-02	4.5E-03
DICHLOROETHYLENE, 1,1-	1.0E+00	1.0E+03			9.8E+02	8.9E+00	1.0E+00
DICHLOROETHYLENE, Cis 1,2-	1.9E-01	5.0E+02			3.4E+02	1.6E+00	1.9E-01
DICHLOROETHYLENE, Trans 1,2-	6.7E-01	1.0E+03			5.5E+02	3.1E+00	6.7E-01
DICHLOROPHENOL, 2,4-	3.0E-01	1.0E+03			1.2E+03		3.0E-01
DICHLOROPROPANE, 1,2-	5.1E-02	5.0E+02			4.5E+01	5.1E-02	1.2E-01
DICHLOROPROPENE, 1,3-	3.3E-02	1.0E+03			1.9E+01	3.3E-02	5.9E-02
DIELDRIN	2.3E-03	2.5E+03			1.6E+00		2.3E-03
DIETHYLPHTHALATE	3.5E-02	1.0E+03			3.2E+05		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	1.0E+03			4.0E+06		3.5E-02
DIMETHYLPHENOL, 2,4-	6.7E-01	5.0E+02			4.9E+03	1.1E+02	6.7E-01
DINITROPHENOL, 2,4-	4.0E-02	1.0E+03			8.0E+02		4.0E-02
DINITROTOLUENE, 2,4-	8.5E-04	1.0E+03			6.4E+01		8.5E-04
1,4 DIOXANE	1.8E-03	1.0E+03			7.4E+02		1.8E-03
DIOXIN (2,3,7,8-TCDD)	2.4E-04	no criteria			2.4E-04		
ENDOSULFAN	4.6E-03	1.0E+03			2.4E+03		4.6E-03
ENDRIN	6.5E-04	1.0E+03			1.6E+02		6.5E-04
ETHANOL	4.5E+01	1.0E+03					4.5E+01
ETHYLBENZENE	3.3E+00	4.0E+02			4.0E+02	3.9E+02	3.3E+00
FLUORANTHENE	6.0E+01	1.0E+03			1.4E+04		6.0E+01
FLUORENE	8.9E+00	1.0E+03			1.5E+04	1.6E+02	8.9E+00
HEPTACHLOR	1.4E-02	2.5E+03			6.3E+00		1.4E-02
HEPTACHLOR EPOXIDE	1.5E-02	2.5E+03			3.6E+00		1.5E-02
HEXACHLOROBENZENE	1.1E+01	1.0E+03			1.1E+01		7.9E+02
HEXACHLOROBUTADIENE	1.0E+00	1.0E+03			1.2E+02		1.0E+00

TABLE C-1. [1]DEEP SOIL SCREENING LEVELS (>3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	[2]RESIDENTIAL LAND USE (mg/kg) Human Health — Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	1.0E+03			2.4E+01		4.9E-02
HEXACHLOROETHANE	2.4E+00	1.0E+03			4.0E+02		2.4E+00
INDENO(1,2,3-cd)PYRENE	7.7E+00	1.0E+03			1.5E+01		7.7E+00
LEAD	7.5E+02	2.5E+03	7.5E+02	occupational	7.5E+02		
MERCURY	9.8E+01	1.0E+03			9.8E+01	(Use soil gas)	
METHOXYCHLOR	1.9E+01	1.0E+03			2.6E+03		1.9E+01
METHYLENE CHLORIDE	7.7E-02	1.0E+03			3.4E+02	5.2E-01	7.7E-02
METHYL ETHYL KETONE	3.9E+00	1.0E+03			3.4E+04	4.9E+02	3.9E+00
METHYL ISOBUTYL KETONE	2.8E+00	5.0E+02			6.0E+03	1.2E+02	2.8E+00
METHYL MERCURY	4.1E+01	5.0E+02			4.1E+01		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	1.0E+03	9.4E+03	Fluorene	9.4E+03	1.1E+02	2.5E-01
METHYL TERT BUTYL ETHER	2.3E-02	5.0E+02			2.5E+03	2.0E+00	2.3E-02
MOLYBDENUM	2.5E+03	2.5E+03			3.6E+03		
NAPHTHALENE	4.6E-01	1.0E+03			9.7E+01	4.6E-01	3.4E+00
NICKEL	1.0E+03	2.5E+03			1.0E+03		
PENTACHLOROPHENOL	5.3E+00	1.0E+03			1.5E+02		5.3E+00
PERCHLORATE	1.0E-02	2.5E+03			7.1E+01		1.0E-02
PHENANTHRENE	1.1E+01	1.0E+03	1.5E+04	Fluorene	1.5E+04	(Use soil gas)	1.1E+01
PHENOL	7.6E-02	1.0E+03			1.2E+05		7.6E-02
POLYCHLORINATED BIPHENYLS (PCBs)	6.3E+00	1.0E+03			6.7E+00		6.3E+00
PYRENE	8.5E+01	1.0E+03			1.2E+04	8.5E+01	8.5E+01
SELENIUM	2.5E+03	2.5E+03			3.4E+03		
SILVER	2.5E+03	2.5E+03			3.6E+03		
STYRENE	1.5E+00	1.0E+03			1.5E+03	4.5E+02	1.5E+00
tert-BUTYL ALCOHOL	7.3E-02	5.0E+02			3.7E+03	(Use soil gas)	7.3E-02
TETRACHLOROETHANE, 1,1,1,2-	2.4E-02	5.0E+02			2.4E+02	(Use soil gas)	2.4E-02
TETRACHLOROETHANE, 1,1,2,2-	9.1E-03	1.0E+03			2.8E+01	9.1E-03	1.8E-02
TETRACHLOROETHYLENE	8.7E-02	2.3E+02			2.5E+01	8.7E-02	7.0E-01
THALLIUM	4.7E+01	2.5E+03			4.7E+01		
TOLUENE	2.9E+00	6.5E+02			6.5E+02	1.3E+02	2.9E+00
TOXAPHENE	4.2E-04	1.0E+03			2.2E+01		4.2E-04
TPH (gasolines)	1.0E+02	5.0E+03			6.0E+03	(Use soil gas)	1.0E+02
TPH (middle distillates)	1.0E+02	5.0E+03			6.0E+03	(Use soil gas)	1.0E+02
TPH (residual fuels)	1.0E+03	5.0E+03			1.5E+04		1.0E+03
TRICHLOROBENZENE, 1,2,4-	3.8E-01	1.0E+03			4.8E+02	3.8E-01	7.6E+00
TRICHLOROETHANE, 1,1,1-	7.8E+00	1.0E+03			1.2E+03	9.8E+01	7.8E+00
TRICHLOROETHANE, 1,1,2-	3.2E-02	5.0E+02			5.7E+01	3.2E-02	7.0E-02
TRICHLOROETHYLENE	2.6E-01	1.0E+03			1.2E+02	2.6E-01	4.6E-01

TABLE C-1. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
²RESIDENTIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	³RESIDENTIAL LAND USE (mg/kg) Human Health Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
TRICHLOROPHENOL, 2,4,5-	1.8E-01	5.0E+02			1.9E+04	2.3E+01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	1.7E-01	1.0E+03			2.9E+02		1.7E-01
VANADIUM	2.5E+03	2.5E+03			5.0E+03		
VINYL CHLORIDE	6.7E-03	1.0E+03			2.4E+00	6.7E-03	8.5E-02
XYLENES	2.3E+00	4.2E+02		m-xylene RfDs	4.2E+02	3.1E+02	2.3E+00
ZINC	2.5E+03	2.5E+03			2.1E+05		
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	-			-	-	-
Sodium Adsorption Ratio	not applicable	-			-	-	-

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Deep soils defined as soils situated >3 meters below ground surface (or shallower with institutional controls).

2. "Residential Land Use" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

Final Environmental Screening Level is lowest of ceiling values (nuisance concerns etc.), direct-exposure, indoor-air impact, and leaching screening levels.
Assumes soil pH 5.0 to 11.
Soil data should be reported on dry-weight basis (see Section 6.2).
TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Background total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE C-2. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)				Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
			Human Health				
			Substitute Direct Exposure		Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	
			Value	Basis			
ACENAPHTHENE	1.6E+01	5.0E+03			2.1E+04	1.3E+02	1.6E+01
ACENAPHTHYLENE	1.3E+01	2.5E+03	1.5E+04	Fluorene	1.5E+04	(Use soil gas)	1.3E+01
ACETONE	5.0E-01	2.5E+03			1.0E+05	3.3E+03	5.0E-01
ALDRIN	1.5E+00	5.0E+03			1.5E+00		5.0E+00
ANTHRACENE	2.8E+00	2.5E+03			1.2E+05	6.1E+00	2.8E+00
ANTIMONY	2.8E+02	5.0E+03			2.8E+02		
ARSENIC	5.5E+00	5.0E+03	5.5E+00	Background	5.5E+00		
BARIUM	2.5E+03	5.0E+03			2.5E+03		
BENZENE	4.4E-02	1.1E+03			1.6E+01	5.1E-01	4.4E-02
BENZO(a)ANTHRACENE	1.2E+01	2.5E+03			1.5E+01		1.2E+01
BENZO(b)FLUORANTHENE	1.5E+01	2.5E+03			1.5E+01		4.6E+01
BENZO(k)FLUORANTHENE	2.7E+00	2.5E+03			1.5E+01		2.7E+00
BENZO(g,h,i)PERYLENE	2.7E+01	2.5E+03			1.4E+04		2.7E+01
BENZO(a)PYRENE	1.5E+00	2.5E+03			1.5E+00		1.3E+02
BERYLLIUM	3.6E+01	5.0E+03			3.6E+01		
BIPHENYL, 1,1-	6.5E-01	2.5E+03			1.7E+04	(Use soil gas)	6.5E-01
BIS(2-CHLOROETHYL)ETHER	1.8E-04	2.5E+03			5.2E+00	1.2E-02	1.8E-04
BIS(2-CHLOROISOPROPYL)ETHER	5.4E-03	7.9E+02			1.7E+02	(Use soil gas)	5.4E-03
BIS(2-ETHYLHEXYL)PHTHALATE	6.6E+01	2.5E+03			6.4E+03		6.6E+01
BORON	4.6E+04	no critiera			4.6E+04		
BROMODICHLOROMETHANE	3.9E-02	3.0E+03			3.2E+01	3.9E-02	1.9E+00
BROMOFORM	2.2E+00	2.5E+03			2.6E+03		2.2E+00
BROMOMETHANE	3.9E-01	2.5E+03			3.0E+01	5.1E-01	3.9E-01
CADMIUM	3.8E+01	5.0E+03			3.8E+01		
CARBON TETRACHLORIDE	3.4E-02	1.1E+03			8.2E+00	3.4E-02	1.1E-01
CHLORDANE	1.5E+01	5.0E+03			2.1E+01		1.5E+01
CHLOROANILINE, p-	5.3E-02	5.0E+03			1.6E+03		5.3E-02
CHLOROBENZENE	1.5E+00	6.8E+02			6.8E+02	6.2E+00	1.5E+00
CHLOROETHANE	8.5E-01	2.5E+03			2.8E+02	1.8E+00	8.5E-01
CHLOROFORM	2.1E+00	2.5E+03			7.8E+01	3.3E+02	2.1E+00
CHLOROMETHANE	2.0E-01	1.0E+03			2.8E+01	2.0E-01	2.1E-01
CHLOROPHENOL, 2-	1.2E-02	1.0E+03			4.7E+02	2.0E+00	1.2E-02
CHROMIUM (Total)	5.8E+01	5.0E+03	58	Background	5.8E+01		
CHROMIUM III	5.0E+03	5.0E+03			1.1E+06		
CHROMIUM VI	1.8E+00	5.0E+03			1.8E+00		
CHRYSENE	1.9E+01	5.0E+03			1.5E+02		1.9E+01
COBALT	1.0E+01	5.0E+03			1.0E+01		
COPPER	5.0E+03	5.0E+03			2.8E+04		

TABLE C-2. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg) Human Health — Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
CYANIDE (Free)	3.6E-03	1.0E+03			8.2E+03		3.6E-03
DIBENZO(a,h)ANTHTRACENE	4.3E+00	2.5E+03			4.3E+00		9.9E+00
DIBROMOCHLOROMETHANE	5.4E-02	1.0E+03			7.3E+01	5.4E-02	8.3E+00
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	2.5E+03			1.7E+00	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	3.3E-04	2.5E+03			4.6E+00	2.0E-02	3.3E-04
DICHLOROBENZENE, 1,2-	1.1E+00	6.0E+02			6.0E+02	2.1E+01	1.1E+00
DICHLOROBENZENE, 1,3-	7.4E+00	6.0E+02			6.0E+02	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	1.3E-01	2.5E+03			1.9E+02	1.3E-01	5.9E-01
DICHLOROBENZIDINE, 3,3-	7.7E-03	2.5E+03			1.7E+01		7.7E-03
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.1E+02	2.5E+03			1.1E+02		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	7.6E-01	2.5E+03			7.6E+01		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	4.3E+00	5.0E+03			7.6E+01		4.3E+00
DICHLOROETHANE, 1,1-	2.0E-01	1.7E+03			7.6E+01	8.9E-01	2.0E-01
DICHLOROETHANE, 1,2-	4.5E-03	2.5E+03			2.5E+02	7.0E-02	4.5E-03
DICHLOROETHYLENE, 1,1-	1.0E+00	1.5E+03			3.1E+01	2.1E+01	1.0E+00
DICHLOROETHYLENE, Cis 1,2-	1.9E-01	1.0E+03			9.8E+02	3.6E+00	1.9E-01
DICHLOROETHYLENE, Trans 1,2-	6.7E-01	2.5E+03			3.4E+02	7.3E+00	6.7E-01
DICHLOROPHENOL, 2,4-	3.0E-01	2.5E+03			5.5E+02		3.0E-01
DICHLOROPROPANE, 1,2-	1.2E-01	1.0E+03			1.2E+03	1.4E-01	1.2E-01
DICHLOROPROPENE, 1,3-	5.9E-02	1.4E+03			4.5E+01	9.3E-02	5.9E-02
DIELDRIN	2.3E-03	5.0E+03			1.9E+01		2.3E-03
DIETHYLPHTHALATE	3.5E-02	2.5E+03			1.6E+00		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	2.5E+03			3.2E-05		3.5E-02
DIMETHYLPHENOL, 2,4-	6.7E-01	1.0E+03			4.0E-06		6.7E-01
DINITROPHENOL, 2,4-	4.0E-02	2.5E+03			4.9E-03	3.0E+02	4.0E-02
DINITROTOLUENE, 2,4-	8.5E-04	2.5E+03			8.0E+02		8.5E-04
1,4 DIOXANE	1.8E-03	2.5E+03			6.4E+01		1.8E-03
DIOXIN (2,3,7,8-TCDD)	2.4E-04	no criteria			7.4E+02		
ENDOSULFAN	4.6E-03	2.5E+03			2.4E-04		4.6E-03
ENDRIN	6.5E-04	2.5E+03			2.4E+03		6.5E-04
ETHANOL	4.5E+01	2.5E+03			1.6E+02		4.5E+01
ETHYLBENZENE	3.3E+00	4.0E+02			4.0E+02	3.9E+02	3.3E+00
FLUORANTHENE	6.0E+01	2.5E+03			1.4E+04		6.0E+01
FLUORENE	8.9E+00	2.5E+03			1.5E+04	1.6E+02	8.9E+00
HEPTACHLOR	1.4E-02	5.0E+03			6.3E+00		1.4E-02
HEPTACHLOR EPOXIDE	1.5E-02	5.0E+03			3.6E+00		1.5E-02
HEXACHLOROBENZENE	1.1E+01	2.5E+03			1.1E+01		7.9E+02
HEXACHLOROBUTADIENE	1.0E+00	2.5E+03			1.2E+02		1.0E+00

TABLE C-2. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)				Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
			Human Health				
			Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	2.5E+03			2.4E+01		4.9E-02
HEXACHLOROETHANE	2.4E+00	2.5E+03			4.0E+02		2.4E+00
INDENO(1,2,3-cd)PYRENE	7.7E+00	2.5E+03			1.5E+01		7.7E+00
LEAD	7.5E+02	5.0E+03	7.5E+02	occupational	7.5E+02		
MERCURY	9.8E+01	2.5E+03			9.8E+01	(Use soil gas)	
METHOXYCHLOR	1.9E+01	2.5E+03			2.6E+03		1.9E+01
METHYLENE CHLORIDE	7.7E-02	2.3E+03			3.4E+02	1.5E+00	7.7E-02
METHYL ETHYL KETONE	3.9E+00	2.5E+03			3.4E+04	1.3E+03	3.9E+00
METHYL ISOBUTYL KETONE	2.8E+00	1.0E+03			6.0E+03	3.1E+02	2.8E+00
METHYL MERCURY	4.1E+01	1.0E+03			4.1E+01		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	2.5E+03	9.4E+03	Fluorene	9.4E+03	1.1E+02	2.5E-01
METHYL TERT BUTYL ETHER	2.3E-02	1.0E+03			2.5E+03	5.6E+00	2.3E-02
MOLYBDENUM	3.6E+03	5.0E+03			3.6E+03		
NAPHTHALENE	1.5E+00	2.5E+03			9.7E+01	1.5E+00	3.4E+00
NICKEL	1.0E+03	5.0E+03			1.0E+03		
PENTACHLOROPHENOL	5.3E+00	2.5E+03			1.5E+02		5.3E+00
PERCHLORATE	1.0E-02	5.0E+03			7.1E+01		1.0E-02
PHENANTHRENE	1.1E+01	2.5E+03	1.5E+04	Fluorene	1.5E+04	(Use soil gas)	1.1E+01
PHENOL	7.6E-02	2.5E+03			1.2E+05		7.6E-02
POLYCHLORINATED BIPHENYLS (PCBs)	6.3E+00	2.5E+03			6.7E+00		6.3E+00
PYRENE	8.5E+01	2.5E+03			1.2E+04	8.5E+01	8.5E+01
SELENIUM	3.4E+03	5.0E+03			3.4E+03		
SILVER	3.6E+03	5.0E+03			3.6E+03		
STYRENE	1.5E+00	1.5E+03			1.5E+03	1.1E+03	1.5E+00
tert-BUTYL ALCOHOL	7.3E-02	1.0E+03			3.7E+03	(Use soil gas)	7.3E-02
TETRACHLOROETHANE, 1,1,1,2-	2.4E-02	1.0E+03			2.4E+02	(Use soil gas)	2.4E-02
TETRACHLOROETHANE, 1,1,2,2-	1.8E-02	2.0E+03			2.8E+01	2.5E-02	1.8E-02
TETRACHLOROETHYLENE	2.4E-01	2.3E+02			2.5E+01	2.4E-01	7.0E-01
THALLIUM	4.7E+01	5.0E+03			4.7E+01		
TOLUENE	2.9E+00	6.5E+02			6.5E+02	3.1E+02	2.9E+00
TOXAPHENE	4.2E-04	2.5E+03			2.2E+01		4.2E-04
TPH (gasolines)	1.0E+02	5.0E+03			6.0E+03	(Use soil gas)	1.0E+02
TPH (middle distillates)	1.0E+02	5.0E+03			6.0E+03	(Use soil gas)	1.0E+02
TPH (residual fuels)	1.0E+03	5.0E+03			1.5E+04		1.0E+03
TRICHLOROBENZENE, 1,2,4-	1.0E+00	2.5E+03			4.8E+02	1.0E+00	7.6E+00
TRICHLOROETHANE, 1,1,1-	7.8E+00	1.2E+03			1.2E+03	2.3E+02	7.8E+00
TRICHLOROETHANE, 1,1,2-	7.0E-02	1.0E+03			5.7E+01	8.9E-02	7.0E-02
TRICHLOROETHYLENE	4.6E-01	1.3E+03			1.2E+02	7.3E-01	4.6E-01

TABLE C-2. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg) Human Health — Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) Drinking Water Resource Table G
TRICHLOROPHENOL, 2,4,5-	1.8E-01	1.0E+03			1.9E+04	6.1E-01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	1.7E-01	2.5E+03			2.9E+02		1.7E-01
VANADIUM	5.0E+03	5.0E+03			5.0E+03		
VINYL CHLORIDE	1.9E-02	2.5E+03			2.4E+00	1.9E-02	8.5E-02
XYLENES	2.3E+00	4.2E+02		m-xylene RfDs	4.2E+02	4.2E+02	2.3E+00
ZINC	5.0E+03	5.0E+03			2.1E+05		
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	-			-	-	-
Sodium Adsorption Ratio	not applicable	-			-	-	-

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Deep soils defined as soils situated >3 meters below ground surface (or shallower with institutional controls).

Final Environmental Screening Level is lowest of ceiling values (nuisance concerns etc.), direct-exposure, indoor-air impact, and leaching screening levels.

Assumes soil pH 5.0 to 11.

Soil data should be reported on dry-weight basis (see Section 6.2).

TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

Background total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE D-1. [1]DEEP SOIL SCREENING LEVELS (>3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

[2]RESIDENTIAL LAND USE (mg/kg)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	Human Health				Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
			Substitute Direct Exposure		Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	
			Value	Basis			
ACENAPHTHENE	1.9E+01	2.5E+03			2.1E+04	1.3E+02	1.9E+01
ACENAPHTHYLENE	1.3E-01	1.0E+03	1.5E+04	Fluorene	1.5E+04	(Use soil gas)	1.3E-01
ACETONE	5.0E-01	1.0E+03			1.0E+05	1.4E+03	5.0E-01
ALDRIN	1.5E+00	2.5E+03			1.5E+00		5.0E+00
ANTHRACENE	2.8E+00	1.0E+03			1.2E+05	6.1E+00	5.0E+00
ANTIMONY	2.8E+02	2.5E+03			2.8E+02		2.8E+00
ARSENIC	5.5E+00	2.5E+03	5.5E+00	Background	5.5E+00		
BARIUM	2.5E+03	2.5E+03			2.5E+03		
BENZENE	1.8E-01	1.0E+03			1.6E+01	1.8E-01	2.0E+00
BENZO(a)ANTHRACENE	1.2E-01	1.0E+03			1.5E+01		1.2E+01
BENZO(b)FLUORANTHENE	1.5E+01	1.0E+03			1.5E+01		4.6E+01
BENZO(k)FLUORANTHENE	1.5E+01	1.0E+03			1.5E+01		3.7E+01
BENZO(g,h,i)PERYLENE	2.7E-01	1.0E+03			1.4E+04		2.7E+01
BENZO(a)PYRENE	1.5E+00	1.0E+03			1.5E+00		1.3E+02
BERYLLIUM	3.6E+01	2.5E+03			3.6E+01		
BIPHENYL, 1,1-	6.5E+00	1.0E+03			1.7E+04	(Use soil gas)	6.5E+00
BIS(2-CHLOROETHYL)ETHER	3.7E-03	1.0E+03			5.2E+00	3.7E-03	7.8E-01
BIS(2-CHLOROISOPROPYL)ETHER	6.6E-01	7.9E+02			1.7E+02	(Use soil gas)	6.6E-01
BIS(2-ETHYLHEXYL)PHTHALATE	5.3E+02	1.0E+03			6.4E+03		5.3E+02
BORON	4.6E+04	no criteria			4.6E+04		
BROMODICHLOROMETHANE	1.4E-02	2.5E+03			3.2E-01	1.4E-02	3.2E+00
BROMOFORM	6.9E+01	1.0E+03			2.6E-03		6.9E+01
BROMOMETHANE	2.2E-01	1.0E+03			3.0E-01	2.2E-01	6.4E+00
CADMIUM	3.8E+01	2.5E+03			3.8E+01		
CARBON TETRACHLORIDE	1.2E-02	1.0E+03			8.2E+00	1.2E-02	2.0E+00
CHLORDANE	1.5E+01	2.5E+03			2.1E+01		1.5E+01
CHLOROANILINE, p-	5.3E-02	2.5E+03			1.6E+03		5.3E-02
CHLOROBENZENE	1.5E+00	6.8E+02			6.8E+02	2.7E+00	1.5E+00
CHLOROETHANE	6.3E-01	1.0E+03			2.8E+02	6.3E+00	8.5E-01
CHLOROFORM	9.8E+00	1.0E+03			7.8E+01	1.4E+02	9.8E+00
CHLOROMETHANE	7.0E-02	5.0E+02			2.8E+01	7.0E-02	6.4E+00
CHLOROPHENOL, 2-	1.2E-01	5.0E+02			4.7E+02	7.8E-01	1.2E-01
CHROMIUM (Total)	5.8E+01	2.5E+03	58	Background	5.8E+01		
CHROMIUM III	2.5E+03	2.5E+03			1.1E+06		
CHROMIUM VI	1.8E+00	2.5E+03			1.8E+00		
CHRYSENE	2.3E+01	2.5E+03			1.5E+02		2.3E+01
COBALT	1.0E+01	2.5E+03			1.0E+01		
COPPER	2.5E+03	2.5E+03			2.8E+04		

TABLE D-1. [1]DEEP SOIL SCREENING LEVELS (>3m bgs)
[2]RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	RESIDENTIAL LAND USE (mg/kg) Human Health Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
CYANIDE (Free)	3.6E-03	5.0E+02			8.2E+03		3.6E-03
DIBENZO(a,h)ANTHTRACENE	4.3E+00	1.0E+03			4.3E+00		1.4E+02
DIBROMOCHLOROMETHANE	1.9E-02	5.0E+02			7.3E+01	1.9E-02	1.4E+01
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	1.0E+03			1.7E+00	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	7.3E-03	1.0E+03			4.6E+00	7.3E-03	1.0E+00
DICHLOROBENZENE, 1,2-	1.6E+00	6.0E+02			6.0E+02	8.9E+00	1.6E+00
DICHLOROBENZENE, 1,3-	7.4E+00	6.0E+02			6.0E+02	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	4.6E-02	1.0E+03			1.9E+02	4.6E-02	1.8E+00
DICHLOROBENZIDINE, 3,3-	1.7E+01	1.0E+03			1.7E+01		6.6E+01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.1E+02	1.0E+03			1.1E+02		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	7.6E+01	1.0E+03			7.6E+01		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	4.3E+00	2.5E+03			7.6E+01		4.3E+00
DICHLOROETHANE, 1,1-	3.2E-01	1.0E+03			2.5E+02	3.2E-01	1.9E+00
DICHLOROETHANE, 1,2-	2.5E-02	1.0E+03			3.1E+01	2.5E-02	1.8E+00
DICHLOROETHYLENE, 1,1-	4.3E+00	1.0E+03			9.8E+02	8.9E+00	4.3E+00
DICHLOROETHYLENE, Cis 1,2-	1.6E+00	5.0E+02			3.4E+02	1.6E+00	1.8E+01
DICHLOROETHYLENE, Trans 1,2-	3.1E+00	1.0E+03			5.5E+02	3.1E+00	3.9E+01
DICHLOROPHENOL, 2,4-	3.0E+00	1.0E+03			1.2E+03		3.0E+00
DICHLOROPROPANE, 1,2-	5.1E-02	5.0E+02			4.5E+01	5.1E-02	2.5E+00
DICHLOROPROPENE, 1,3-	3.3E-02	1.0E+03			1.9E+01	3.3E-02	6.2E+00
DIELDRIN	2.3E-03	2.5E+03			1.6E+00		2.3E-03
DIETHYLPHTHALATE	3.5E-02	1.0E+03			3.2E+05		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	1.0E+03			4.0E+06		3.5E-02
DIMETHYLPHENOL, 2,4-	7.4E-01	5.0E+02			4.9E+03		7.4E-01
DINITROPHENOL, 2,4-	2.1E-01	1.0E+03			8.0E+02	1.1E+02	2.1E-01
DINITROTOLUENE, 2,4-	8.6E-01	1.0E+03			6.4E+01		8.6E-01
1,4 DIOXANE	3.0E+01	1.0E+03			7.4E+02		3.0E+01
DIOXIN (2,3,7,8-TCDD)	2.4E-04	no criteria			2.4E-04		
ENDOSULFAN	4.6E-03	1.0E+03			2.4E+03		4.6E-03
ENDRIN	6.5E-04	1.0E+03			1.6E+02		6.5E-04
ETHANOL	4.5E+01	1.0E+03					4.5E+01
ETHYLBENZENE	3.2E+01	4.0E+02			4.0E+02	3.9E+02	3.2E+01
FLUORANTHENE	6.0E+01	1.0E+03			1.4E+04		6.0E+01
FLUORENE	8.9E+00	1.0E+03			1.5E+04		8.9E+00
HEPTACHLOR	1.4E-02	2.5E+03			6.3E+00	1.6E+02	1.4E-02
HEPTACHLOR EPOXIDE	1.5E-02	2.5E+03			3.6E+00		1.5E-02
HEXACHLOROBENZENE	1.1E+01	1.0E+03			1.1E+01		7.9E+02
HEXACHLOROBUTADIENE	2.3E+01	1.0E+03			1.2E+02		2.3E+01

TABLE D-1. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
²RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	²RESIDENTIAL LAND USE (mg/kg) Human Health				Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
			Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	1.0E+03			2.4E+01		4.9E-02
HEXACHLOROETHANE	4.1E+01	1.0E+03			4.0E+02		4.1E+01
INDENO(1,2,3-cd)PYRENE	7.7E+00	1.0E+03			1.5E+01		7.7E+00
LEAD	7.5E+02	2.5E+03	7.5E+02	occupational	7.5E+02		
MERCURY	9.8E+01	1.0E+03			9.8E+01	(Use soil gas)	
METHOXYCHLOR	1.9E+01	1.0E+03			2.6E+03		1.9E+01
METHYLENE CHLORIDE	5.2E-01	1.0E+03			3.4E+02	5.2E-01	3.4E+01
METHYL ETHYL KETONE	1.3E+01	1.0E+03			3.4E+04	4.9E+02	1.3E+01
METHYL ISOBUTYL KETONE	3.9E+00	5.0E+02			6.0E+03	1.2E+02	3.9E+00
METHYL MERCURY	4.1E+01	5.0E+02			4.1E+01		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	1.0E+03	9.4E+03	Fluorene	9.4E+03	1.1E+02	2.5E-01
METHYL TERT BUTYL ETHER	2.0E+00	5.0E+02			2.5E+03	2.0E+00	8.4E+00
MOLYBDENUM	2.5E+03	2.5E+03			3.6E+03		
NAPHTHALENE	4.6E-01	1.0E+03			9.7E+01	4.6E-01	4.8E+00
NICKEL	1.0E+03	2.5E+03			1.0E+03		
PENTACHLOROPHENOL	4.2E+01	1.0E+03			1.5E+02		4.2E-01
PERCHLORATE	1.2E+00	2.5E+03			7.1E+01		1.2E+00
PHENANTHRENE	1.1E+01	1.0E+03	1.5E+04	Fluorene	1.5E+04		1.1E+01
PHENOL	1.9E+01	1.0E+03			1.2E+05	(Use soil gas)	1.9E+01
POLYCHLORINATED BIPHENYLS (PCBs)	6.3E+00	1.0E+03			6.7E+00		6.3E+00
PYRENE	8.5E+01	1.0E+03			1.2E+04	8.5E+01	8.5E+01
SELENIUM	2.5E+03	2.5E+03			3.4E+03		
SILVER	2.5E+03	2.5E+03			3.6E+03		
STYRENE	1.5E+01	1.0E+03			1.5E+03	4.5E+02	1.5E+01
tert-BUTYL ALCOHOL	1.1E+02	5.0E+02			3.7E+03	(Use soil gas)	1.1E+02
TETRACHLOROETHANE, 1,1,1,2-	1.6E+01	5.0E+02			2.4E+02	(Use soil gas)	1.6E+01
TETRACHLOROETHANE, 1,1,2,2-	9.1E-03	1.0E+03			2.8E+01	9.1E-03	3.4E+00
TETRACHLOROETHYLENE	8.7E-02	2.3E+02			2.5E+01	8.7E-02	1.7E+01
THALLIUM	4.7E+01	2.5E+03			4.7E+01		
TOLUENE	9.3E+00	6.5E+02			6.5E+02	1.3E+02	9.3E+00
TOXAPHENE	4.2E-04	1.0E+03			2.2E+01		4.2E-04
TPH (gasolines)	4.0E+02	5.0E+03			6.0E+03	(Use soil gas)	4.0E+02
TPH (middle distillates)	5.0E+02	5.0E+03			6.0E+03	(Use soil gas)	5.0E+02
TPH (residual fuels)	1.0E+03	5.0E+03			1.5E+04		1.0E+03
TRICHLOROBENZENE, 1,2,4-	3.8E-01	1.0E+03			4.8E+02	3.8E-01	7.6E+00
TRICHLOROETHANE, 1,1,1-	7.8E+00	1.0E+03			1.2E+03	9.8E+01	7.8E+00
TRICHLOROETHANE, 1,1,2-	3.2E-02	5.0E+02			5.7E+01	3.2E-02	4.8E+00
TRICHLOROETHYLENE	2.6E-01	1.0E+03			1.2E+02	2.6E-01	3.3E+01

TABLE D-1. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
²RESIDENTIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	²RESIDENTIAL LAND USE (mg/kg) — Human Health — Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
TRICHLOROPHENOL, 2,4,5-	1.8E-01	5.0E+02			1.9E+04	2.3E+01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	1.6E+02	1.0E+03			2.9E+02	-	1.6E+02
VANADIUM	2.5E+03	2.5E+03			5.0E+03	-	-
VINYL CHLORIDE	6.7E-03	1.0E+03			2.4E+00	6.7E-03	6.6E-01
XYLENES	1.1E+01	4.2E+02		m-xylene RfDs	4.2E+02	3.1E+02	1.1E+01
ZINC	2.5E+03	2.5E+03			2.1E+05	-	-
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	-			-	-	
Sodium Adsorption Ratio	not applicable	-			-	-	

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:
1. Deep soils defined as soils situated >3 meters below ground surface (or shallower with institutional controls).
2. "Residential Land Use" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

Final Environmental Screening Level is lowest of ceiling values (nuisance concerns etc.), direct-exposure, indoor-air impact, and leaching screening levels.
Assumes soil pH 5.0 to 11.
Soil data should be reported on dry-weight basis (see Section 6.2).
TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Background total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE D-2. [1]DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)				
			Human Health				Groundwater Protection (Soil Leaching)
			Substitute Direct Exposure		Direct Exposure	Vapor Intrusion Into Buildings	NON-Drinking Water Resource
			Value	Basis	Table K-3	Table E-1b	Table G
ACENAPHTHENE	1.9E+01	5.0E+03			2.1E+04	1.3E+02	1.9E+01
ACENAPHTHYLENE	1.3E+01	2.5E+03	1.5E+04	Fluorene	1.5E+04	(Use soil gas)	1.3E-01
ACETONE	5.0E-01	2.5E+03			1.0E+05	3.3E+03	5.0E-01
ALDRIN	1.5E+00	5.0E+03			1.5E+00		5.0E+00
ANTHRACENE	2.8E+00	2.5E+03			1.2E+05	6.1E+00	5.0E+00
ANTIMONY	2.8E+02	5.0E+03			1.2E+05	6.1E+00	2.8E+00
ARSENIC	5.5E+00	5.0E+03	5.5E+00	Background	2.8E+02		
BARIUM	2.5E+03	5.0E+03			5.5E+00		
BENZENE	5.1E-01	1.1E+03			2.5E+03		
BENZO(a)ANTHRACENE	1.2E-01	2.5E+03			1.6E+01	5.1E-01	2.0E+00
BENZO(b)FLUORANTHENE	1.5E-01	2.5E+03			1.5E+01		1.2E+01
BENZO(k)FLUORANTHENE	1.5E-01	2.5E+03			1.5E+01		4.6E+01
BENZO(g,h,i)PERYLENE	2.7E-01	2.5E+03			1.5E+01		3.7E+01
BENZO(a)PYRENE	1.5E+00	2.5E+03			1.4E+04		2.7E+01
BERYLLIUM	3.6E-01	5.0E+03			1.5E+00		1.3E+02
BIPHENYL, 1,1-	6.5E+00	2.5E+03			3.6E+01		
BIS(2-CHLOROETHYL)ETHER	1.2E-02	2.5E+03			1.7E+04	(Use soil gas)	6.5E+00
BIS(2-CHLOROISOPROPYL)ETHER	6.6E-01	7.9E+02			5.2E+00	1.2E-02	7.8E-01
BIS(2-ETHYLHEXYL)PHTHALATE	5.3E+02	2.5E+03			1.7E+02	(Use soil gas)	6.6E-01
BORON	4.6E+04	no critiera			6.4E+03		5.3E+02
BROMODICHLOROMETHANE	3.9E-02	3.0E+03			4.6E+04		
BROMOFORM	6.9E+01	2.5E+03			3.2E+01	3.9E-02	3.2E+00
BROMOMETHANE	5.1E-01	2.5E+03			2.6E+03		6.9E+01
CADMIUM	3.8E+01	5.0E+03			3.0E+01	5.1E-01	6.4E+00
CARBON TETRACHLORIDE	3.4E-02	1.1E+03			3.8E+01		
CHLORDANE	1.5E+01	5.0E+03			8.2E+00	3.4E-02	2.0E+00
CHLOROANILINE, p-	5.3E-02	5.0E+03			2.1E+01		1.5E+01
CHLOROBENZENE	1.5E+00	6.8E+02			1.6E+03		5.3E-02
CHLOROETHANE	8.5E-01	2.5E+03			6.8E+02	6.2E+00	1.5E+00
CHLOROFORM	9.8E+00	2.5E+03			2.8E+02	1.8E+00	8.5E-01
CHLOROMETHANE	2.0E-01	1.0E+03			7.8E+01	3.3E+02	9.8E+00
CHLOROPHENOL, 2-	1.2E-01	1.0E+03			2.8E+01	2.0E-01	6.4E+00
CHROMIUM (Total)	5.8E+01	5.0E+03	58	Background	4.7E+02	2.0E+00	1.2E-01
CHROMIUM III	5.0E+03	5.0E+03			5.8E+01		
CHROMIUM VI	1.8E+00	5.0E+03			1.1E+06		
CHRYSENE	2.3E+01	5.0E+03			1.8E+00		
COBALT	1.0E+01	5.0E+03			1.5E+02		2.3E+01
COPPER	5.0E+03	5.0E+03			1.0E+01		
					2.8E+04		

TABLE D-2. [1]DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg)				Groundwater Protection (Soil Leaching)
			Human Health			Vapor Intrusion Into Buildings Table E-1b	NON-Drinking Water Resource Table G
			Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3		
CYANIDE (Free)	3.6E-03	1.0E+03			8.2E+03		3.6E-03
DIBENZO(a,h)ANTHTRACENE	4.3E+00	2.5E+03			4.3E+00		1.4E+02
DIBROMOCHLOROMETHANE	5.4E-02	1.0E+03			7.3E+01	5.4E-02	1.4E-01
1,2-DIBROMO-3-CHLOROPROPANE	4.5E-03	2.5E+03			1.7E+00	(Use soil gas)	4.5E-03
DIBROMOETHANE, 1,2-	2.0E-02	2.5E+03			4.6E+00	2.0E-02	1.0E+00
DICHLOROBENZENE, 1,2-	1.6E+00	6.0E+02			6.0E+02	2.1E+01	1.6E+00
DICHLOROBENZENE, 1,3-	7.4E+00	6.0E+02			6.0E+02	(Use soil gas)	7.4E+00
DICHLOROBENZENE, 1,4-	1.3E-01	2.5E+03			1.9E+02	1.3E-01	1.8E+00
DICHLOROBENZIDINE, 3,3-	1.7E+01	2.5E+03			1.7E+01		6.6E+01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.1E+02	2.5E+03			1.1E+02		7.5E+02
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	7.6E+01	2.5E+03			7.6E+01		1.1E+03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	4.3E+00	5.0E+03			7.6E+01		4.3E+00
DICHLOROETHANE, 1,1-	8.9E-01	1.7E+03			2.5E+02	8.9E-01	1.9E+00
DICHLOROETHANE, 1,2-	7.0E-02	2.5E+03			3.1E+01	7.0E-02	1.8E+00
DICHLOROETHYLENE, 1,1-	4.3E+00	1.5E+03			9.8E+02	2.1E+01	4.3E+00
DICHLOROETHYLENE, Cis 1,2-	3.6E+00	1.0E+03			3.4E+02	3.6E+00	1.8E+01
DICHLOROETHYLENE, Trans 1,2-	7.3E+00	2.5E+03			5.5E+02	7.3E+00	3.9E+01
DICHLOROPHENOL, 2,4-	3.0E+00	2.5E+03			1.2E+03		3.0E+00
DICHLOROPROPANE, 1,2-	1.4E-01	1.0E+03			4.5E+01	1.4E-01	2.5E+00
DICHLOROPROPENE, 1,3-	9.3E-02	1.4E+03			1.9E+01	9.3E-02	6.2E+00
DIELDRIN	2.3E-03	5.0E+03			1.6E+00		2.3E-03
DIETHYLPHTHALATE	3.5E-02	2.5E+03			3.2E+05		3.5E-02
DIMETHYLPHTHALATE	3.5E-02	2.5E+03			4.0E+06		3.5E-02
DIMETHYLPHENOL, 2,4-	7.4E-01	1.0E+03			4.9E+03	3.0E+02	7.4E-01
DINITROPHENOL, 2,4-	2.1E-01	2.5E+03			8.0E+02		2.1E-01
DINITROTOLUENE, 2,4-	8.6E-01	2.5E+03			6.4E+01		8.6E-01
1,4 DIOXANE	3.0E+01	2.5E+03			7.4E+02		3.0E+01
DIOXIN (2,3,7,8-TCDD)	2.4E-04	no criteria			2.4E-04		
ENDOSULFAN	4.6E-03	2.5E+03			2.4E+03		4.6E-03
ENDRIN	6.5E-04	2.5E+03			1.6E+02		6.5E-04
ETHANOL	4.5E-01	2.5E+03					4.5E+01
ETHYLBENZENE	3.2E-01	4.0E+02	4.0E+02		4.0E+02	3.9E+02	3.2E+01
FLUORANTHENE	6.0E+01	2.5E+03			1.4E+04		6.0E+01
FLUORENE	8.9E+00	2.5E+03			1.5E+04	1.6E+02	8.9E+00
HEPTACHLOR	1.4E-02	5.0E+03			6.3E+00		1.4E-02
HEPTACHLOR EPOXIDE	1.5E-02	5.0E+03			3.6E+00		1.5E-02
HEXACHLOROBENZENE	1.1E+01	2.5E+03			1.1E+01		7.9E+02
HEXACHLOROBUTADIENE	2.3E+01	2.5E+03			1.2E+02		2.3E+01

TABLE D-2. ¹DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

CHEMICAL PARAMETER	Final ESL	Gross Contamination Ceiling Value (Odors, etc.) Table H-3	COMMERCIAL / INDUSTRIAL LAND USE (mg/kg) Human Health – Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	Groundwater Protection (Soil Leaching) NON-Drinking Water Resource Table G
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	4.9E-02	2.5E+03			2.4E+01		4.9E-02
HEXACHLOROETHANE	4.1E+01	2.5E+03			4.0E+02		4.1E+01
INDENO(1,2,3-cd)PYRENE	7.7E+00	2.5E+03			1.5E+01		7.7E+00
LEAD	7.5E+02	5.0E+03	7.5E+02	occupational	7.5E+02		
MERCURY	9.8E+01	2.5E+03			9.8E+01	(Use soil gas)	
METHOXYCHLOR	1.9E+01	2.5E+03			2.6E+03		1.9E+01
METHYLENE CHLORIDE	1.5E+00	2.3E+03			3.4E+02	1.5E+00	3.4E+01
METHYL ETHYL KETONE	1.3E-01	2.5E+03			3.4E+04	1.3E+03	1.3E+01
METHYL ISOBUTYL KETONE	3.9E+00	1.0E+03			6.0E+03	3.1E+02	3.9E+00
METHYL MERCURY	4.1E+01	1.0E+03			4.1E+01		
METHYLNAPHTHALENE (total 1- & 2-)	2.5E-01	2.5E+03	9.4E+03	Fluorene	9.4E+03	1.1E+02	2.5E-01
MOLYBDENUM	5.6E+00	1.0E+03			2.5E+03	5.6E+00	8.4E+00
NAPHTHALENE	3.6E+03	5.0E+03			3.6E+03		
NICKEL	1.5E+00	2.5E+03			9.7E+01	1.5E+00	4.8E+00
PENTACHLOROPHENOL	1.0E+03	5.0E+03			1.0E+03		
PERCHLORATE	4.2E+01	2.5E+03			1.5E+02		4.2E+01
PHENANTHRENE	1.2E+00	5.0E+03			7.1E+01		1.2E+00
PHENOL	1.1E+01	2.5E+03	1.5E+04	Fluorene	1.5E+04		1.1E+01
POLYCHLORINATED BIPHENYLS (PCBs)	1.9E+01	2.5E+03			1.2E+05	(Use soil gas)	1.9E+01
PYRENE	6.3E+00	2.5E+03			6.7E+00		6.3E+00
SELENIUM	8.5E+01	2.5E+03			1.2E+04	8.5E+01	8.5E+01
SILVER	3.4E+03	5.0E+03			3.4E+03		
STYRENE	3.6E+03	5.0E+03			3.6E+03		
tert-BUTYL ALCOHOL	1.5E+01	1.5E+03			1.5E+03	1.1E+03	1.5E+01
TETRACHLOROETHANE, 1,1,1,2-	1.1E+02	1.0E+03			3.7E+03	(Use soil gas)	1.1E+02
TETRACHLOROETHANE, 1,1,2,2-	1.6E+01	1.0E+03			2.4E+02	(Use soil gas)	1.6E+01
TETRACHLOROETHYLENE	2.5E-02	2.0E+03			2.8E+01	2.5E-02	3.4E+00
THALLIUM	2.4E-01	2.3E+02			2.5E+01	2.4E-01	1.7E+01
TOLUENE	4.7E+01	5.0E+03			4.7E+01		
TOXAPHENE	9.3E+00	6.5E+02			6.5E+02	3.1E+02	9.3E+00
TPH (gasolines)	4.2E-04	2.5E+03			2.2E+01		4.2E-04
TPH (middle distillates)	4.0E+02	5.0E+03			6.0E+03	(Use soil gas)	4.0E+02
TPH (residual fuels)	5.0E+02	5.0E+03			6.0E+03	(Use soil gas)	5.0E+02
TRICHLOROBENZENE, 1,2,4-	1.0E+03	5.0E+03			1.5E+04		1.0E+03
TRICHLOROETHANE, 1,1,1-	1.0E+00	2.5E+03			4.8E+02	1.0E+00	7.6E+00
TRICHLOROETHANE, 1,1,2-	7.8E+00	1.2E+03			1.2E+03	2.3E+02	7.8E+00
TRICHLOROETHYLENE	8.9E-02	1.0E+03			5.7E+01	8.9E-02	4.8E+00
	7.3E-01	1.3E+03			1.2E+02	7.3E-01	3.3E-01

Table D-2 (Subsurf, NDW, CI)

TABLE D-2. [1]DEEP SOIL SCREENING LEVELS (>3m bgs)
COMMERCIAL / INDUSTRIAL LAND USE
(potentially impacted groundwater IS NOT a current or potential drinking water resource)

| CHEMICAL PARAMETER | Final ESL | Gross Contamination Ceiling Value (Odors, etc.) Table H-3 | COMMERCIAL / INDUSTRIAL LAND USE (mg/kg) Human Health | | | | | Groundwater Protection (Soil Leaching) |
			Substitute Direct Exposure Value	Basis	Direct Exposure Table K-3	Vapor Intrusion Into Buildings Table E-1b	NON-Drinking Water Resource Table G	
TRICHLOROPHENOL, 2,4,5-	1.8E-01	1.0E+03			1.9E+04	6.1E+01	1.8E-01	
TRICHLOROPHENOL, 2,4,6-	1.6E+02	2.5E+03			2.9E+02		1.6E+02	
VANADIUM	5.0E+03	5.0E+03			5.0E+03			
VINYL CHLORIDE	1.9E-02	2.5E+03			2.4E+00	1.9E-02	6.6E-01	
XYLENES	1.1E+01	4.2E+02		m-xylene RfDs	4.2E+02	4.2E+02	1.1E+01	
ZINC	5.0E+03	5.0E+03			2.1E+05			
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	-			-	-	-	
Sodium Adsorption Ratio	not applicable	-			-	-	-	

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Deep soils defined as soils situated >3 meters below ground surface (or shallower with institutional controls).

Final Environmental Screening Level is lowest of ceiling values (nuisance concerns etc.), direct-exposure, indoor-air impact, and leaching screening levels.
Assumes soil pH 5.0 to 11.
Soil data should be reported on dry-weight basis (see Section 6.2).
TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Background total Cr based on mean soil values presented in LBNL 2002 (refer to Section 3.2.4 and Volume 1, Figure 4).

TABLE E-1a. GROUNDWATER SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State	[1] Residential Land Use Vadose-Zone Soil Type		Commercial/Industrial Land Use Vadose-Zone Soil Type	
		[2] High Permeability (ug/L)	[3] Low/Moderate Permeability (ug/L)	[2] High Permeability (ug/L)	[3] Low/Moderate Permeability (ug/L)
#ACENAPHTHENE	V S	4.2E+03	4.2E+03	4.2E+03	4.2E+03
ACENAPHTHYLENE	V S	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
#ACETONE	V L	5.3E+07	4.6E+07	1.5E+08	1.3E+08
ALDRIN	NV S				
#ANTHRACENE	V S	4.3E+01	4.3E+01	4.3E+01	4.3E+01
ANTIMONY	NV S				
ARSENIC	NV S				
BARIUM	NV S				
#BENZENE	V L	5.4E+02	1.9E+03	1.8E+03	6.4E+03
BENZO(a)ANTHRACENE	NV S				
BENZO(b)FLUORANTHENE	NV S				
BENZO(k)FLUORANTHENE	NV S				
BENZO(g,h,i)PERYLENE	NV S				
BENZO(a)PYRENE	NV S				
BERYLLIUM	NV S				
BIPHENYL, 1,1-	V S	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
BIS(2-CHLOROETHYL)ETHER	V L	6.5E+01	5.0E+01	2.2E+02	1.7E+02
BIS(2-CHLOROISOPROPYL)ETHER	V L	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
BIS(2-ETHYLHEXYL)PHTHALATE	NV S				
BORON	NV S				
BROMODICHLOROMETHANE	V L	1.7E+02	3.0E+02	5.6E+02	1.0E+03
BROMOFORM	NV S				
BROMOMETHANE	V G	5.8E+02	2.0E+03	1.6E+03	5.6E+03
CADMIUM	NV S				
CARBON TETRACHLORIDE	V L	9.3E+00	3.9E+01	3.1E+01	1.3E+02
CHLORDANE	NV S				
CHLOROANILINE, p-	NV S				
CHLOROBENZENE	V L	1.3E+04	4.2E+04	3.7E+04	1.2E+05
CHLOROETHANE	V G	8.2E+02	3.2E+03	2.7E+03	1.1E+04
CHLOROFORM	V L	3.3E+02	1.1E+03	1.1E+03	3.8E+03
CHLOROMETHANE	V G	4.1E+01	1.8E+02	1.4E+02	6.0E+02
CHLOROPHENOL, 2-	V L	5.3E+03	1.4E+04	1.5E+04	4.0E+04
CHROMIUM (Total)	NV S				
CHROMIUM III	NV S				
CHROMIUM VI	NV S				
CHRYSENE	NV S	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
COBALT	NV S				

TABLE E-1a. GROUNDWATER SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

| CHEMICAL PARAMETER | Physical State | | [1]Residential Land Use Vadose-Zone Soil Type | | Commercial/Industrial Land Use Vadose-Zone Soil Type | |
			[2]High Permeability (ug/L)	[3]Low/Moderate Permeability (ug/L)	[2]High Permeability (ug/L)	[3]Low/Moderate Permeability (ug/L)
COPPER	NV	S				
CYANIDE (Free)	NV	S	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
DIBENZO(a,h)ANTHTRACENE	NV	S				
DIBROMOCHLOROMETHANE	V	S	1.7E+02	3.9E+02	5.7E+02	1.3E+03
1,2-DIBROMO-3-CHLOROPROPANE	V	L	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
DIBROMOETHANE, 1,2-	V	S	1.5E+02	2.3E+02	5.1E+02	7.7E+02
DICHLOROBENZENE, 1,2-	V	L	7.7E+04	1.6E+05	1.6E+05	1.6E+05
DICHLOROBENZENE, 1,3-	V	L	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
DICHLOROBENZENE, 1,4-	V	S	3.4E+02	9.5E+02	1.1E+03	3.2E+03
DICHLOROBENZIDINE, 3,3-	NV	S				
DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV	S				
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	NV	S				
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV	S				
DICHLOROETHANE, 1,1-	V	L	1.0E+03	3.5E+03	3.4E+03	1.2E+04
DICHLOROETHANE, 1,2-	V	L	2.0E+02	4.9E+02	6.9E+02	1.7E+03
DICHLOROETHYLENE, 1,1-	V	L	6.3E+03	2.6E+04	1.8E+04	7.4E+04
DICHLOROETHYLENE, Cis 1,2-	V	L	6.2E+03	1.9E+04	1.7E+04	5.4E+04
DICHLOROETHYLENE, Trans 1,2-	V	L	6.7E+03	2.4E+04	1.9E+04	6.8E+04
DICHLOROPHENOL, 2,4-	NV	S				
DICHLOROPROPANE, 1,2-	V	L	2.8E+02	8.5E+02	9.3E+02	2.8E+03
DICHLOROPROPENE, 1,3-	V	L	5.3E+01	2.1E+02	1.8E+02	7.0E+02
DIELDRIN	NV	S				
DIETHYLPHTHALATE	NV	S				
DIMETHYLPHTHALATE	NV	S				
#DIMETHYLPHENOL, 2,4-	V	S	2.5E+06	2.0E+06	7.1E+06	5.5E+06
DINITROPHENOL, 2,4-	NV	S				
DINITROTOLUENE, 2,4-	NV	S				
1,4 DIOXANE	NV	L				
DIOXIN (2,3,7,8-TCDD)	NV	S				
ENDOSULFAN	NV	S				
ENDRIN	NV	S				
ETHANOL	NV	S	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
#ETHYLBENZENE	V	L	1.7E+05	1.7E+05	1.7E+05	1.7E+05
FLUORANTHENE	NV	S				
#FLUORENE	V	S	1.9E+03	1.9E+03	1.9E+03	1.9E+03
HEPTACHLOR	NV	S				
HEPTACHLOR EPOXIDE	NV	S				

TABLE E-1a. GROUNDWATER SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State		Residential Land Use		Commercial/Industrial Land Use	
			Vadose-Zone Soil Type		Vadose-Zone Soil Type	
			[2]High Permeability (ug/L)	[3]Low/Moderate Permeability (ug/L)	[2]High Permeability (ug/L)	[3]Low/Moderate Permeability (ug/L)
HEXACHLOROBENZENE	NV	S				
HEXACHLOROBUTADIENE	NV	S				
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV	S				
HEXACHLOROETHANE	NV	S				
INDENO(1,2,3-cd)PYRENE	NV	S				
LEAD	NV	S				
MERCURY	V	S	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
METHOXYCHLOR	NV	S				
METHYLENE CHLORIDE	V	L	2.4E+03	7.0E+03	8.1E+03	2.4E+04
#METHYL ETHYL KETONE	V	L	2.4E+07	1.9E+07	6.8E+07	5.4E+07
#METHYL ISOBUTYL KETONE	V	L	3.0E+06	2.3E+06	8.4E+06	6.5E+06
METHYL MERCURY	NV	S				
#METHYLNAPHTHALENE (total 1- & 2-)	V	S	2.6E+04	2.6E+04	2.6E+04	2.6E+04
METHYL TERT BUTYL ETHER	V	L	2.4E+04	4.5E+04	8.0E+04	1.5E+05
MOLYBDENUM	NV	S				
#NAPHTHALENE	V	S	3.2E+03	5.0E+03	1.1E+04	1.7E+04
NICKEL	NV	S				
PENTACHLOROPHENOL	NV	S				
PERCHLORATE	NV	S				
PHENANTHRENE	V	S	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
PHENOL	NV	S				
POLYCHLORINATED BIPHENYLS (PCBs)	NV	S				
#PYRENE	V	S	1.4E+02	1.4E+02	1.4E+02	1.4E+02
SELENIUM	NV	S				
SILVER	NV	S				
#STYRENE	V	L	3.1E+05	3.1E+05	3.1E+05	3.1E+05
tert-BUTYL ALCOHOL			(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
TETRACHLOROETHANE, 1,1,1,2-	V	L	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
TETRACHLOROETHANE, 1,1,2,2-	V	L	1.9E+02	2.9E+02	6.4E+02	9.7E+02
TETRACHLOROETHYLENE	V	L	1.2E+02	5.0E+02	4.2E+02	1.7E+03
THALLIUM	NV	S				
#TOLUENE	V	L	3.8E+05	5.3E+05	5.3E+05	5.3E+05
TOXAPHENE	NV	S				
TPH (gasolines)	V	L	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
TPH (middle distillates)	V	L	(Use soil gas)	(Use soil gas)	(Use soil gas)	(Use soil gas)
TPH (residual fuels)	NV	L/S				
TRICHLOROBENZENE, 1,2,4-	V	L	2.5E+03	4.5E+03	7.1E+03	1.2E+04

TABLE E-1a. GROUNDWATER SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State		Residential Land Use Vadose-Zone Soil Type		Commercial/Industrial Land Use Vadose-Zone Soil Type	
			[2]High Permeability (ug/L)	[3]Low/Moderate Permeability (ug/L)	[2]High Permeability (ug/L)	[3]Low/Moderate Permeability (ug/L)
TRICHLOROETHANE, 1,1,1-	V	L	1.3E+05	5.2E+05	3.6E+05	1.3E+06
TRICHLOROETHANE, 1,1,2-	V	L	3.5E+02	7.6E+02	1.2E+03	2.5E+03
TRICHLOROETHYLENE	V	L	5.3E+02	2.0E+03	1.8E+03	6.9E+03
TRICHLOROPHENOL, 2,4,5-	V	S	8.3E+05	7.3E+05	1.2E+06	1.2E+06
TRICHLOROPHENOL, 2,4,6-	NV	S				
VANADIUM	NV	S				
VINYL CHLORIDE	V	G	3.8E+00	1.7E+01	1.3E+01	5.8E+01
#XYLENES	V	L	1.6E+05	1.6E+05	1.6E+05	1.6E+05
ZINC	NV	S				

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. "Residential" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).
2. High permeability soil model: One meter dry sandy soil (92% sand, 5% silt, 3% clay) over one meter moist clayey loam (33% sand, 34% silt, 33% clay).
3. Low/Moderate permeability soil model: One meter dry loamy sand (83% sand, 11% silt, 6% clay) over one meter moist silt (7% sand, 87% silt, 6% clay).
4. For inclusion in Tier 1 screening levels, all groundwater assumed to potentially migrate under a residential area. Screening levels for protection
   of indoor air under a residential exposure scenario carried forward for use at both residential and commercial/industrial sites (see Table F series).

Screening levels calculated using spreadsheet provided with *User's Guide for the Johnson and Ettinger Indoor Air model (1991) for Subsurface Vapor
Intrusion Into Buildings* (USEPA 2003). Assumed vadose-zone thickness/depth to groundwater three meters. See Appendix 1 text for model details.
Physical state of chemical at ambient conditions (V - volatile, NV - nonvolatile, S -id, L - liquid, G - gas).
Chemical considered to be "volatile" if Henry's number (atm m3/mole) >0.00001 and molecular weight <200.
Dibromochloromethane, dibromochloropropane and pyrene considered volatile for purposes of modeling (USEPA 2004).
Target cancer risk = 1E-06, Target Hazard Quotient = 0.2
"#": Nonchlorinated VOCs (except MTBE) adjusted upwards by factor of ten to account for assumed biodegradation in vadose-zone prior to emission
at surface.

TABLE E-1b. SOIL SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)
(Use with Soil Gas Screening Levels for sites with significant VOC releases)

CHEMICAL PARAMETER	Physical State		[1]Residenital Exposure (mg/kg)	Commercial/Industrial Exposure (mg/kg)
#ACENAPHTHENE	V	S	1.3E+02	1.3E+02
ACENAPHTHYLENE	V	S	(Use soil gas)	(Use soil gas)
#ACETONE	V	L	1.4E+03	3.3E+03
ALDRIN	NV	S		
#ANTHRACENE	V	S	6.1E+00	6.1E+00
ANTIMONY	NV	S		
ARSENIC	NV	S		
BARIUM	NV	S		
#BENZENE	V	L	1.8E-01	5.1E-01
BENZO(a)ANTHRACENE	NV	S		
BENZO(b)FLUORANTHENE	NV	S		
BENZO(k)FLUORANTHENE	NV	S		
BENZO(g,h,i)PERYLENE	NV	S		
BENZO(a)PYRENE	NV	S		
BERYLLIUM	NV	S		
BIPHENYL, 1,1-	V	S	(Use soil gas)	(Use soil gas)
BIS(2-CHLOROETHYL)ETHER	V	L	3.7E-03	1.2E-02
BIS(2-CHLOROISOPROPYL)ETHER	V	L	(Use soil gas)	(Use soil gas)
BIS(2-ETHYLHEXYL)PHTHALATE	NV	S		
BORON	NV	S		
BROMODICHLOROMETHANE	V	L	1.4E-02	3.9E-02
BROMOFORM	NV	S		
BROMOMETHANE	V	G	2.2E-01	5.1E-01
CADMIUM	NV	S		
CARBON TETRACHLORIDE	V	L	1.2E-02	3.4E-02
CHLORDANE	NV	S		
CHLOROANILINE, p-	NV	S		
CHLOROBENZENE	V	L	2.7E+00	6.2E+00
CHLOROETHANE	V	G	6.3E-01	1.8E+00
CHLOROFORM	V	L	1.4E+02	3.3E+02
CHLOROMETHANE	V	G	7.0E-02	2.0E-01
CHLOROPHENOL, 2-	V	L	7.8E-01	2.0E+00
CHROMIUM (Total)	NV	S		
CHROMIUM III	NV	S		
CHROMIUM VI	NV	S		
CHRYSENE	NV	S		
COBALT	NV	S		
COPPER	NV	S		
CYANIDE (Free)	NV	S		
DIBENZO(a,h)ANTHTRACENE	NV	S		
DIBROMOCHLOROMETHANE	V	S	1.9E-02	5.4E-02
1,2-DIBROMO-3-CHLOROPROPANE	V	L	(Use soil gas)	(Use soil gas)
DIBROMOETHANE, 1,2-	V	S	7.3E-03	2.0E-02
DICHLOROBENZENE, 1,2-	V	L	8.9E+00	2.1E+01
DICHLOROBENZENE, 1,3-	V	L	(Use soil gas)	(Use soil gas)
DICHLOROBENZENE, 1,4-	V	S	4.6E-02	1.3E-01
DICHLOROBENZIDINE, 3,3-	NV	S		
DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV	S		
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	NV	S		
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV	S		
DICHLOROETHANE, 1,1-	V	L	3.2E-01	8.9E-01

TABLE E-1b. SOIL SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)
(Use with Soil Gas Screening Levels for sites with significant VOC releases)

CHEMICAL PARAMETER	Physical State		Residenital Exposure (mg/kg)	Commercial/Industrial Exposure (mg/kg)
DICHLOROETHANE, 1,2-	V	L	2.5E-02	7.0E-02
DICHLOROETHYLENE, 1,1-	V	L	8.9E+00	2.1E+01
DICHLOROETHYLENE, Cis 1,2-	V	L	1.6E+00	3.6E+00
DICHLOROETHYLENE, Trans 1,2-	V	L	3.1E+00	7.3E+00
DICHLOROPHENOL, 2,4-	NV	S		
DICHLOROPROPANE, 1,2-	V	L	5.1E-02	1.4E-01
DICHLOROPROPENE, 1,3-	V	L	3.3E-02	9.3E-02
DIELDRIN	NV	S		
DIETHYLPHTHALATE	NV	S		
DIMETHYLPHTHALATE	NV	S		
#DIMETHYLPHENOL, 2,4-	V	S	1.1E+02	3.0E+02
DINITROPHENOL, 2,4-	NV	S		
DINITROTOLUENE, 2,4-	NV	S		
1,4 DIOXANE	NV	L		
DIOXIN (2,3,7,8-TCDD)	NV	S		
ENDOSULFAN	NV	S		
ENDRIN	NV	S		
ETHANOL	NV	L	(Use soil gas)	(Use soil gas)
#ETHYLBENZENE	V	L	3.9E+02	3.9E+02
FLUORANTHENE	NV	S		
#FLUORENE	V	S	1.6E+02	1.6E+02
HEPTACHLOR	NV	S		
HEPTACHLOR EPOXIDE	NV	S		
HEXACHLOROBENZENE	NV	S		
HEXACHLOROBUTADIENE	NV	S		
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV	S		
HEXACHLOROETHANE	NV	S		
INDENO(1,2,3-cd)PYRENE	NV	S		
LEAD	NV	S		
MERCURY	V	S	(Use soil gas)	(Use soil gas)
METHOXYCHLOR	NV	S		
METHYLENE CHLORIDE	V	L	5.2E-01	1.5E+00
#METHYL ETHYL KETONE	V	L	4.9E+02	1.3E+03
#METHYL ISOBUTYL KETONE	V	L	1.2E+02	3.1E+02
METHYL MERCURY	NV	S		
#METHYLNAPHTHALENE (total 1- & 2-)	V	S	1.1E+02	1.1E+02
METHYL TERT BUTYL ETHER	V	L	2.0E+00	5.6E+00
MOLYBDENUM	NV	S		
#NAPHTHALENE	V	S	4.6E-01	1.5E+00
NICKEL	NV	S		
PENTACHLOROPHENOL	NV	S		
PERCHLORATE	NV	S		
PHENANTHRENE	V	S	(Use soil gas)	(Use soil gas)
PHENOL	NV	S		
POLYCHLORINATED BIPHENYLS (PCBs)	NV	S		
#PYRENE	V	S	8.5E+01	8.5E+01
SELENIUM	NV	S		
SILVER	NV	S		
#STYRENE	V	L	4.5E+02	1.1E+03
tert-BUTYL ALCOHOL	V	L	(Use soil gas)	(Use soil gas)

TABLE E-1b. SOIL SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)
(Use with Soil Gas Screening Levels for sites with significant VOC releases)

CHEMICAL PARAMETER	Physical State		'Residenital Exposure (mg/kg)	Commercial/Industrial Exposure (mg/kg)
TETRACHLOROETHANE, 1,1,1,2-	V	L	(Use soil gas)	(Use soil gas)
TETRACHLOROETHANE, 1,1,2,2-	V	L	9.1E-03	2.5E-02
TETRACHLOROETHYLENE	V	L	8.7E-02	2.4E-01
THALLIUM	NV	S		
#TOLUENE	V	L	1.3E+02	3.1E+02
TOXAPHENE	NV	S		
TPH (gasolines)	V	L	(Use soil gas)	(Use soil gas)
TPH (middle distillates)	V	L	(Use soil gas)	(Use soil gas)
TPH (residual fuels)	NV	L/S		
TRICHLOROBENZENE, 1,2,4-	V	L	3.8E-01	1.0E+00
TRICHLOROETHANE, 1,1,1-	V	L	9.8E+01	2.3E+02
TRICHLOROETHANE, 1,1,2-	V	L	3.2E-02	8.9E-02
TRICHLOROETHYLENE	V	L	2.6E-01	7.3E-01
TRICHLOROPHENOL, 2,4,5-	V	S	2.3E+01	6.1E+01
TRICHLOROPHENOL, 2,4,6-	NV	S		
VANADIUM	NV	S		
VINYL CHLORIDE	V	G	6.7E-03	1.9E-02
#XYLENES	V	L	3.1E+02	4.2E+02
ZINC	NV	S		

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:
1. "Residential" screening levels generally considered adequate for other sensitive uses (e.g., day-care
   centers, hospitals, etc.).

Screening levels calculated using spreadhseet provided with *User's Guide for the Johnson and Ettinger Indoor Air Model (1991) for Subsurface Vapor Intrusion Into Buildings* (USEPA 2003 and updates).
Soil model: Two meters dry sandy soil (92% sand, 5% silt, 3% clay) directly underlying building foundation.
Physical state of chemical at ambient conditions (V - volatile, NV - nonvolatile, S -solid, L - liquid, G - gas).
Chemical considered to be "volatile" if Henry's number (atm m3/mole) >0.00001 and molecular weight <200.
Dibromochloromethane, dibromochloropropane and pyrene considered volatile for purposes of modeling (USEPA 2004).
Target cancer risk = 1E-06, Target Hazard Quotient = 0.2
"#": Nonchlorinated VOCs (except MTBE) adjusted upwards by factor of ten to account for assumed biodegradation in vadose-zone prior to emission at surface.

TABLE E-2. [1]SHALLOW SOIL GAS SCREENING LEVELS FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State	[2]Residential Exposure			Commercial/Industrial Land Use		
		Lowest Residential (ug/m^3)	Carcinogenic Effects (ug/m^3)	Noncarcinogenic Effects (ug/m^3)	Lowest C/I (ug/m^3)	Carcinogenic Effects (ug/m^3)	Noncarcinogenic Effects (ug/m^3)
ACENAPHTHENE	V S	4.4E+04		4.4E+04	1.2E+05		1.2E+05
ACENAPHTHYLENE	V S	2.9E+04		2.9E+04	8.2E+04		8.2E+04
ACETONE	V L	6.6E+05		6.6E+05	1.8E+06		1.8E+06
ALDRIN	NV S						
ANTHRACENE	V S	2.2E+05		2.2E+05	6.1E+05		6.1E+05
ANTIMONY	NV S						
ARSENIC	NV S						
BARIUM	NV S						
BENZENE	V L	8.5E+01	8.5E+01	1.2E+04	2.9E+02	2.9E+02	3.5E+04
BENZO(a)ANTHRACENE	NV S						
BENZO(b)FLUORANTHENE	NV S						
BENZO(k)FLUORANTHENE	NV S						
BENZO(g,h,i)PERYLENE	NV S						
BENZO(a)PYRENE	NV S						
BERYLLIUM	NV S						
BIPHENYL, 1,1-	V S	3.7E+04		3.7E+04	1.0E+05		1.0E+05
BIS(2-CHLOROETHYL)ETHER	V L	3.4E+00	3.4E+00		1.1E+01	1.1E+01	
BIS(2-CHLOROISOPROPYL)ETHER	V L	2.4E+02	2.4E+02	2.9E+04	8.2E+02	8.2E+02	8.2E+04
BIS(2-ETHYLHEXYL)PHTHALATE	NV S						
BORON	NV S						
BROMODICHLOROMETHANE	V L	6.6E+01	6.6E+01	1.5E+04	2.2E+02	2.2E+02	4.1E+04
BROMOFORM	NV S						
BROMOMETHANE	V G	1.0E+03		1.0E+03	2.9E+03		2.9E+03
CADMIUM	NV S						
CARBON TETRACHLORIDE	V L	5.7E+01	5.7E+01	8.3E+03	1.9E+02	1.9E+02	2.3E+04
CHLORDANE	NV S						
CHLOROANILINE, p-	NV S						
CHLOROBENZENE	V L	1.2E+04		1.2E+04	3.5E+04		3.5E+04
CHLOROETHANE	V G	2.9E+03	2.9E+03	2.1E+06	9.9E+03	9.9E+03	5.9E+06
CHLOROFORM	V L	4.5E+02	4.5E+02	1.0E+04	1.5E+03	1.5E+03	2.9E+04
CHLOROMETHANE	V G	3.3E+02	3.3E+02	6.3E+04	1.1E+03	1.1E+03	1.8E+05
CHLOROPHENOL, 2-	V L	3.7E+03		3.7E+03	1.0E+04		1.0E+04
CHROMIUM (Total)	NV S						
CHROMIUM III	NV S						
CHROMIUM VI	NV S						
CHRYSENE	NV S						
COBALT	NV S						
COPPER	NV S						
CYANIDE (Free)	NV S						

TABLE E-2. [1]SHALLOW SOIL GAS SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State		[2]Residential Exposure			Commercial/Industrial Land Use		
			Lowest Residential (ug/m³)	Carcinogenic Effects (ug/m³)	Noncarcinogenic Effects (ug/m³)	Lowest C/I (ug/m³)	Carcinogenic Effects (ug/m³)	Noncarcinogenic Effects (ug/m³)
DIBENZO(a,h)ANTHTRACENE	NV	S						
DIBROMOCHLOROMETHANE	V	S	9.1E+01	9.1E+01	1.5E+04	3.0E+02	3.0E+02	4.1E+04
1,2-DIBROMO-3-CHLOROPROPANE	V	L	1.2E+00	1.2E+00	4.2E+01	4.1E+00	4.1E+00	1.2E+02
DIBROMOETHANE, 1,2-	V	S	3.4E+01	3.4E+01	1.9E+03	1.1E+02	1.1E+02	5.3E+03
DICHLOROBENZENE, 1,2-	V	L	4.2E+04		4.2E+04	1.2E+05		1.2E+05
DICHLOROBENZENE, 1,3-	V	L	2.2E+04		2.2E+04	6.1E+04		6.1E+04
DICHLOROBENZENE, 1,4-	V	S	2.1E+02	2.1E+02	1.7E+05	7.2E+02	7.2E+02	4.7E+05
DICHLOROBENZIDINE, 3,3-	NV	S						
DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV	S						
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	NV	S						
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV	S						
DICHLOROETHANE, 1,1-	V	L	1.5E+03	1.5E+03	1.0E+05	5.0E+03	5.0E+03	2.9E+05
DICHLOROETHANE, 1,2-	V	L	1.2E+02	1.2E+02	1.0E+03	3.9E+02	3.9E+02	2.9E+03
DICHLOROETHYLENE, 1,1-	V	L	4.2E+04		4.2E+04	1.2E+05		1.2E+05
DICHLOROETHYLENE, Cis 1,2-	V	L	7.3E+03		7.3E+03	2.0E+04		2.0E+04
DICHLOROETHYLENE, Trans 1,2-	V	L	1.5E+04		1.5E+04	4.1E+04		4.1E+04
DICHLOROPHENOL, 2,4-	NV	S						
DICHLOROPROPANE, 1,2-	V	L	2.4E+02	2.4E+02	8.0E+02	7.9E+02	7.9E+02	2.2E+03
DICHLOROPROPENE, 1,3-	V	L	1.5E+02	1.5E+02	1.5E+04	5.2E+02	5.2E+02	4.1E+04
DIELDRIN	NV	S						
DIETHYLPHTHALATE	NV	S						
DIMETHYLPHTHALATE	NV	S						
DIMETHYLPHENOL, 2,4-	V	S	1.5E+04		1.5E+04	4.1E+04		4.1E+04
DINITROPHENOL, 2,4-	NV	S						
DINITROTOLUENE, 2,4-	NV	S						
1,4 DIOXANE	NV	L						
DIOXIN (2,3,7,8-TCDD)	NV	S						
ENDOSULFAN	NV	S						
ENDRIN	NV	S						
ETHANOL	NV	L	1.9E+07			3.8E+07		
ETHYLBENZENE	V	L	4.2E+05		4.2E+05	1.2E+06		1.2E+06
FLUORANTHENE	NV	S						
FLUORENE	V	S	2.9E+04		2.9E+04	8.2E+04		8.2E+04
HEPTACHLOR	NV	S						
HEPTACHLOR EPOXIDE	NV	S						
HEXACHLOROBENZENE	NV	S						
HEXACHLOROBUTADIENE	NV	S						
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV	S						
HEXACHLOROETHANE	NV	S						

TABLE E-2. ¹SHALLOW SOIL GAS SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State		²Residential Exposure			Commercial/Industrial Land Use		
			Lowest Residential (ug/m³)	Carcinogenic Effects (ug/m³)	Noncarcinogenic Effects (ug/m³)	Lowest C/I (ug/m³)	Carcinogenic Effects (ug/m³)	Noncarcinogenic Effects (ug/m³)
INDENO(1,2,3-cd)PYRENE	NV	S						
LEAD	NV	S						
MERCURY	V	S	1.9E+01		1.9E+01	5.3E+01		5.3E+01
METHOXYCHLOR	NV	S						
METHYLENE CHLORIDE	V	L	2.4E+03	2.4E+03	6.3E+05	8.2E+03	8.2E+03	1.8E+06
METHYL ETHYL KETONE	V	L	2.1E+05		2.1E+05	5.9E+05		5.9E+05
METHYL ISOBUTYL KETONE	V	L	1.7E+04		1.7E+04	4.7E+04		4.7E+04
METHYL MERCURY	NV	S						
METHYLNAPHTHALENE (total 1- & 2-)	V	S	2.9E+04		2.9E+04	8.2E+04		8.2E+04
METHYL TERT BUTYL ETHER	V	L	9.4E+03	9.4E+03	1.7E+06	3.1E+04	3.1E+04	4.7E+06
MOLYBDENUM	NV	S						
NAPHTHALENE	V	S	7.1E+01	7.1E+01	1.9E+03	2.4E+02	2.4E+02	5.3E+03
NICKEL	NV	S						
PENTACHLOROPHENOL	NV	S						
PERCHLORATE	NV	S						
PHENANTHRENE	V	S	2.9E+04		2.9E+04	8.2E+04		8.2E+04
PHENOL	NV	S						
POLYCHLORINATED BIPHENYLS (PCBs)	NV	S						
PYRENE	V	S	2.2E+04		2.2E+04	6.1E+04		6.1E+04
SELENIUM	NV	S						
SILVER	NV	S						
STYRENE	V	L	2.1E+05		2.1E+05	5.9E+05		5.9E+05
tert-BUTYL ALCOHOL	V	L	2.6E+03	2.6E+03	2.2E+04	8.7E+03	8.7E+03	6.1E+04
TETRACHLOROETHANE, 1,1,1,2-	V	L	3.3E+02	3.3E+02	2.2E+04	1.1E+03	1.1E+03	6.1E+04
TETRACHLOROETHANE, 1,1,2,2-	V	L	4.3E+01	4.3E+01	4.4E+04	1.4E+02	1.4E+02	1.2E+05
TETRACHLOROETHYLENE	V	L	4.1E+02	4.1E+02	7.3E+03	1.4E+03	1.4E+03	2.0E+04
THALLIUM	NV	S						
TOLUENE	V	L	6.3E+04		6.3E+04	1.8E+05		1.8E+05
TOXAPHENE	NV	S						
TPH (gasolines)	V	L	2.6E+04		2.6E+04	7.2E+04		7.2E+04
TPH (middle distillates)	V	L	2.6E+04		2.6E+04	7.2E+04		7.2E+04
TPH (residual fuels)	NV	L/S						
TRICHLOROBENZENE, 1,2,4-	V	L	7.3E+02		7.3E+02	2.0E+03		2.0E+03
TRICHLOROETHANE, 1,1,1-	V	L	4.6E+05		4.6E+05	1.3E+06		1.3E+06
TRICHLOROETHANE, 1,1,2-	V	L	1.5E+02	1.5E+02	2.9E+03	5.0E+02	5.0E+02	8.2E+03
TRICHLOROETHYLENE	V	L	1.2E+03	1.2E+03	1.2E+05	4.1E+03	4.1E+03	3.5E+05
TRICHLOROPHENOL, 2,4,5-	V	S	7.3E+04		7.3E+04	2.0E+05		2.0E+05
TRICHLOROPHENOL, 2,4,6-	NV	S						
VANADIUM	NV	S						

TABLE E-2. ¹SHALLOW SOIL GAS SCREENING LEVELS
FOR EVALUATION OF POTENTIAL VAPOR INTRUSION CONCERNS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State		²Residential Exposure			Commercial/Industrial Land Use		
			Lowest Residential (ug/m³)	Carcinogenic Effects (ug/m³)	Noncarcinogenic Effects (ug/m³)	Lowest C/I (ug/m³)	Carcinogenic Effects (ug/m³)	Noncarcinogenic Effects (ug/m³)
VINYL CHLORIDE	V	G	3.2E+01	3.2E+01	2.1E+04	1.1E+02	1.1E+02	5.8E+04
XYLENES	V	L	1.5E+05		1.5E+05	4.1E+05		4.1E+05
ZINC	NV	S						

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Shallow soil gas defined as soil gas sample data collected within 1.5 meters (five feet) from a building foundation or the ground surface. Assumes very permeable (e.g., sandy) fill material is present below building foundation or could be present below future buildings following redevelopment. Evaluation of deeper soil gas data (e.g., >1.5m bgs) should be carried out on a site-specific basis.

2. "Residential" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

Soil gas screening levels intended to be protective of indoor air quality, calculated for volatile chemicals only.
Physical state of chemical at ambient conditions (V - volatile, NV - nonvolatile, S - solid, L - liquid, G - gas).
Chemical considered to be "volatile" if Henry's number (atm m3/mole) >0.00001 and molecular weight <200 (see Table E-1).
Dibromochloromethane, dibromochloropropane and pyrene considered volatile for purposes of modeling (USEPA 2004).
Target cancer risk = 1E-06, Target Hazard Quotient = 0.2 for all chemicals except TPH (HQ of 0.5 used, see Sections 1.3 and 3.4 of text).
Residential soil gas:indoor air attenuation factor = 0.001 (1/1000). Commercial/industrial soil gas:indoor air attenuation factor = 0.0005 (1/2000).
Soil gas screening level for ethanol based on potential indoor air nuisance concerns (refer to Section 5.3.3 and Table H series).
Soil gas screening levels do not address mass-balance issues. May be overly conservative for sites with low permeability shallow soils or limited soil impacts and no groundwater source of VOCs.
Indoor-air sampling and/or passive vapor mitigation measures may be prudent for sites where concentrations of chemicals in soil gas approach but do not exceed screening levels.

TABLE E-3. INDOOR AIR SCREENING LEVELS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State		Unit Risk Factor URF $(ug/m^3)^{-1}$	Reference Concentration RfC (ug/m^3)	Health-Based Screening Levels						50% Odor Recognition Threshold (Table H-2) (ug/m^3)
					Residential Exposure			Commercial/Industrial Exposure			
					Lowest Residential (ug/m^3)	Indoor Air (carcinogens) (ug/m^3)	Indoor Air (noncarcinogens) (ug/m^3)	Lowest C/I (ug/m^3)	Indoor Air (carcinogens) (ug/m^3)	Indoor Air (noncarcinogens) (ug/m^3)	
ACENAPHTHENE	V	S		2.1E+02	4.4E+01		4.4E+01	6.1E+01		6.1E+01	5.13E+02
ACENAPHTHYLENE	V	S		1.4E+02	2.9E+01		2.9E+01	4.1E+01		4.1E+01	
ACETONE	V	L		3.2E+03	6.6E+02		6.6E+02	9.2E+02		9.2E+02	3.09E+04
ALDRIN	NV	S									2.63E+02
ANTHRACENE	V	S		1.1E+03	2.2E+02		2.2E+02	3.1E+02		3.1E+02	
ANTIMONY	NV	S									-
ARSENIC	NV	S									-
BARIUM	NV	S									-
BENZENE	V	L	2.9E-05	6.0E+01	8.5E-02	8.5E-02	1.2E+01	1.4E-01	1.4E-01	1.7E+01	4.89E+03
BENZO(a)ANTHRACENE	NV	S									
BENZO(b)FLUORANTHENE	NV	S									
BENZO(k)FLUORANTHENE	NV	S									
BENZO(g,h,i)PERYLENE	NV	S									
BENZO(a)PYRENE	NV	S									
BERYLLIUM	NV	S									
BIPHENYL, 1,1-	V	S		1.8E+02	3.7E+01		3.7E+01	5.1E+01		5.1E+01	6.00E+01
BIS(2-CHLOROETHYL)ETHER	V	L	7.1E-04		3.4E-03	3.4E-03		5.7E-03	5.7E-03		2.87E+02
BIS(2-CHLOROISOPROPYL)ETHER	V	L	1.0E-05	1.4E+02	2.4E-01	2.4E-01	2.9E+01	4.1E-01	4.1E-01	4.1E+01	2.24E+03
BIS(2-ETHYLHEXYL)PHTHALATE	NV	S									
BORON	NV	S									
BROMODICHLOROMETHANE	V	L	3.7E-05	7.0E+01	6.6E-02	6.6E-02	1.5E+01	1.1E-01	1.1E-01	2.0E+01	1.10E+07
BROMOFORM	NV	S		7.0E+01							1.35E+04
BROMOMETHANE	V	G		4.9E+00	1.0E+00		1.0E+00	1.4E+00		1.4E+00	8.00E+04
CADMIUM	NV	S									
CARBON TETRACHLORIDE	V	L	4.3E-05	4.0E+01	5.7E-02	5.7E-02	8.3E+00	9.5E-02	9.5E-02	1.2E+01	6.30E+04
CHLORDANE	NV	S									8.40E+00
CHLOROANILINE, p-	NV	S									
CHLOROBENZENE	V	L		6.0E+01	1.2E+01		1.2E+01	1.7E+01		1.7E+01	1.00E+03
CHLOROETHANE	V	G	8.3E-07	1.0E+04	2.9E+00	2.9E+00	2.1E+03	4.9E+00	4.9E+00	3.0E+03	3.80E+05
CHLOROFORM	V	L	5.4E-06	4.9E+01	4.5E-01	4.5E-01	1.0E+01	7.5E-01	7.5E-01	1.4E+01	4.22E+05
CHLOROMETHANE	V	G	7.4E-06	3.0E+02	3.3E-01	3.3E-01	6.3E+01	5.5E-01	5.5E-01	8.8E+01	1.90E+01
CHLOROPHENOL, 2-	V	L		1.8E+01	3.7E+00		3.7E+00	5.1E+00		5.1E+00	
CHROMIUM (Total)	NV	S									
CHROMIUM III	NV	S									
CHROMIUM VI	NV	S									
CHRYSENE	NV	S									
COBALT	NV	S									
COPPER	NV	S									
CYANIDE (Free)	NV	S									6.52E+02
DIBENZO(a,h)ANTHRACENE	NV	S	2.7E-05								
DIBROMOCHLOROMETHANE	V	S		7.0E+01	9.1E-02	9.1E-02	1.5E+01	1.5E-01	1.5E-01	2.0E+01	

TABLE E-3. INDOOR AIR SCREENING LEVELS
(volatile chemicals only)

| CHEMICAL PARAMETER | Physical State | Unit Risk Factor URF (ug/m³)⁻¹ | Reference Concentration RfC (ug/m³) | Health-Based Screening Levels | | | | | | 50% Odor Recognition Threshold (Table H-2) (ug/m³) |
| | | | | Residential Exposure | | | Commercial/Industrial Exposure | | | |
				Lowest Residential (ug/m³)	Indoor Air (carcinogens) (ug/m³)	Indoor Air (noncarcinogens) (ug/m³)	Lowest C/I (ug/m³)	Indoor Air (carcinogens) (ug/m³)	Indoor Air (noncarcinogens) (ug/m³)	
1,2-DIBROMO-3-CHLOROPROPANE	V / L	2.0E-03	2.0E-01	1.2E-03	1.2E-03	4.2E-02	2.0E-03	2.0E-03	5.8E-02	-
DIBROMOETHANE, 1,2-	V / S	7.1E-05	9.1E+00	3.4E-02	3.4E-02	1.9E+00	5.7E-02	5.7E-02	2.7E+00	2.00E+05
DICHLOROBENZENE, 1,2-	V / L		2.0E+02	4.2E+01		4.2E+01	5.8E+01		5.8E+01	3.05E+05
DICHLOROBENZENE, 1,3-	V / L		1.1E+02	2.2E+01		2.2E+01	3.1E+01		3.1E+01	-
DICHLOROBENZENE, 1,4-	V / S	1.1E-05	8.1E+02	2.1E-01	2.1E-01	1.7E+02	3.6E-01	3.6E-01	2.4E+02	1.10E+03
DICHLOROBENZIDINE, 3,3-	NV / S									-
DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV / S									-
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	NV / S									-
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV / S									-
DICHLOROETHANE, 1,1-	V / L	1.6E-06	4.9E+02	1.5E+00	1.5E+00	1.0E+02	2.5E+00	2.5E+00	1.4E+02	1.25E+05
DICHLOROETHANE, 1,2-	V / L	2.1E-05	4.9E+00	1.2E-01	1.2E-01	1.0E+00	2.0E-01	2.0E-01	1.4E+00	2.42E+03
DICHLOROETHYLENE, 1,1-	V / L		2.0E+02	4.2E+01		4.2E+01	5.8E+01		5.8E+01	2.00E+06
DICHLOROETHYLENE, Cis 1,2-	V / L		3.5E+01	7.3E+00		7.3E+00	1.0E+01		1.0E+01	-
DICHLOROETHYLENE, Trans 1,2-	V / L		7.0E+01	1.5E+01		1.5E+01	2.0E+01		2.0E+01	6.73E+04
DICHLOROPHENOL, 2,4-	NV / S									1.40E+03
DICHLOROPROPANE, 1,2-	V / L	1.0E-05	3.9E+00	2.4E-01	2.4E-01	8.0E-01	4.0E-01	4.0E-01	1.1E+00	1.19E+03
DICHLOROPROPENE, 1,3-	V / L	1.6E-05	7.0E+01	1.5E-01	1.5E-01	1.5E+01	2.6E-01	2.6E-01	2.0E+01	4.16E+03
DIELDRIN	NV / S									-
DIETHYLPHTHALATE	NV / S									-
DIMETHYLPHTHALATE	NV / S									-
DIMETHYLPHENOL, 2,4-	V / S		7.0E+01	1.5E+01		1.5E+01	2.0E+01		2.0E+01	1.00E+00
DINITROPHENOL, 2,4-	NV / S									-
DINITROTOLUENE, 2,4-	NV / S									-
1,4 DIOXANE	NV / L									6.12E+05
DIOXIN (2,3,7,8-TCDD)	NV / S									-
ENDOSULFAN	NV / S									-
ENDRIN	NV / S									-
ETHANOL	NV / L			1.9E+04		1.9E+04	1.9E+04			1.92E+04
ETHYLBENZENE	V / L		2.0E+03	4.2E+02		4.2E+02	5.8E+02		5.8E+02	2.00E+03
FLUORANTHENE	NV / S									-
FLUORENE	V / S		1.4E+02	2.9E+01		2.9E+01	4.1E+01		4.1E+01	-
HEPTACHLOR	NV / S									3.00E+02
HEPTACHLOR EPOXIDE	NV / S									3.00E+02
HEXACHLOROBENZENE	NV / S									-
HEXACHLOROBUTADIENE	NV / S									1.20E+04
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV / S									-
HEXACHLOROETHANE	NV / S									-
INDENO(1,2,3-cd)PYRENE	NV / S									-
LEAD	NV / S									-
MERCURY	V / S		9.1E-02	1.9E-02		1.9E-02	2.7E-02		2.7E-02	2.7E-02

| CHEMICAL PARAMETER | Physical State | Unit Risk Factor URF (ug/m³)⁻¹ | Reference Concentration RfC (ug/m³) | Health-Based Screening Levels | | | | | | 50% Odor Recognition Threshold (Table H-2) (ug/m³) |
| | | | | Residential Exposure | | | Commercial/Industrial Exposure | | | |
				Lowest Residential (ug/m³)	Indoor Air (carcinogens) (ug/m³)	Indoor Air (noncarcinogens) (ug/m³)	Lowest CI (ug/m³)	Indoor Air (carcinogens) (ug/m³)	Indoor Air (noncarcinogens) (ug/m³)	
METHOXYCHLOR	NV S									-
METHYLENE CHLORIDE	V L	1.0E-06	3.0E+03	2.4E+00	2.4E+00	6.3E+02	4.1E+00	4.1E+00	8.8E+02	5.60E+05
METHYL ETHYL KETONE	V L		1.0E+03	2.1E+02		2.1E+02	3.0E+02		3.0E+02	3.20E+04
METHYL ISOBUTYL KETONE	V L		8.1E+01	1.7E+01		1.7E+01	2.4E+01		2.4E+01	4.20E+02
METHYL MERCURY	NV S									-
METHYLNAPHTHALENE (total 1- & 2-)	V S		1.4E+02	2.9E+01		2.9E+01	4.1E+01		4.1E+01	6.80E+01
METHYL TERT BUTYL ETHER	V L	2.6E-07	8.0E+03	9.4E+00	9.4E+00	1.7E+03	1.6E+01	1.6E+01	2.3E+03	5.30E+02
MOLYBDENUM	NV S									-
NAPHTHALENE	V S	3.4E-05	9.0E+00	7.1E-02	7.1E-02	1.9E+00	1.2E-01	1.2E-01	2.6E+00	4.40E+02
NICKEL	NV S									-
PENTACHLOROPHENOL	NV S									-
PERCHLORATE	NV S									-
PHENANTHRENE	V S		1.4E+02	2.9E+01		2.9E+01	4.1E+01		4.1E+01	5.50E+01
PHENOL	NV S									1.56E+02
POLYCHLORINATED BIPHENYLS (PCBs)	NV S									-
PYRENE	V S		1.1E+02	2.2E+01		2.2E+01	3.1E+01		3.1E+01	-
SELENIUM	NV S									
SILVER	NV S									
STYRENE	V L		1.0E+03	2.1E+02		2.1E+02	3.0E+02		3.0E+02	1.36E+03
tert-BUTYL ALCOHOL	V L	9.4E-07		2.6E+00	2.6E+00		4.3E+00	4.3E+00		-
TETRACHLOROETHANE, 1,1,1,2-	V L	7.4E-06	1.1E+02	3.3E-01	3.3E-01	2.2E+01	5.5E-01	5.5E-01	3.1E+01	-
TETRACHLOROETHANE, 1,1,2,2-	V L	5.7E-05	2.1E+02	4.3E-02	4.3E-02	4.4E+01	7.2E-02	7.2E-02	6.1E+01	1.05E+04
TETRACHLOROETHYLENE	V L	6.0E-06	3.5E+01	4.1E-01	4.1E-01	7.3E+00	6.8E-01	6.8E-01	1.0E+01	3.17E+04
THALLIUM	NV S									-
TOLUENE	V L		3.0E+02	6.3E+01		6.3E+01	8.8E+01		8.8E+01	3.00E+04
TOXAPHENE	NV S									-
TPH (gasolines)	V L		4.9E+01	2.6E+01		2.6E+01	3.6E+01		3.6E+01	1.00E+02
TPH (middle distillates)	V L		4.9E+01	2.6E+01		2.6E+01	3.6E+01		3.6E+01	1.00E+03
TPH (residual fuels)	NV L/S									-
TRICHLOROBENZENE, 1,2,4-	V L		3.5E+00	7.3E-01		7.3E-01	1.0E+00		1.0E+00	2.20E+04
TRICHLOROETHANE, 1,1,1-	V L		2.2E+03	4.6E+02		4.6E+02	6.4E+02		6.4E+02	6.51E+04
TRICHLOROETHANE, 1,1,2-	V L	1.6E-05	1.4E+01	1.5E-01	1.5E-01	2.9E+00	2.5E-01	2.5E-01	4.1E+00	-
TRICHLOROETHYLENE	V L	2.0E-06	6.0E+02	1.2E+00	1.2E+00	1.2E+02	2.0E+00	2.0E+00	1.2E+02	1.36E+06
TRICHLOROPHENOL, 2,4,5-	V S		3.5E+02	7.3E+01		7.3E+01	1.0E+02		1.0E+02	3.00E-01
TRICHLOROPHENOL, 2,4,6-	NV S									-
VANADIUM	NV S									-

TABLE E-3. INDOOR AIR SCREENING LEVELS
(volatile chemicals only)

CHEMICAL PARAMETER	Physical State		Health-Based Screening Levels									50% Odor Recognition Threshold (Table H-2) (ug/m³)
			Unit Risk Factor URF (ug/m³)⁻¹	Reference Concentration RfC (ug/m³)	Residential Exposure			Commercial/Industrial Exposure				
					Lowest Residential (ug/m³)	Indoor Air (carcinogens) (ug/m³)	Indoor Air (noncarcinogens) (ug/m³)	Lowest C/I (ug/m³)	Indoor Air (carcinogens) (ug/m³)	Indoor Air (noncarcinogens) (ug/m³)	
VINYL CHLORIDE	V	G	7.7E-05	1.0E+02	3.2E-02	3.2E-02	2.1E+01	5.3E-02	5.3E-02	2.9E+01	7.71E+05
XYLENES	V	L		7.0E+02	1.5E+02		1.5E+02	2.0E+02		2.0E+02	4.41E+02
ZINC	NV	S									-

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. "Residential" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

Target cancer risk = 1E-06, Target Hazard Quotient = 0.2 for all chemicals except TPH (HQ of 0.5 used, see Sections 1.3 and 3.4 of text).
Physical state of chemical at ambient conditions (V - volatile, NV - nonvolatile, S - solid, L - liquid, G - gas).
Chemical considered to be "volatile" if Henry's number (atm m3/mole) >0.00001 and molecular weight <200 (see Table E-1).
Dibromochloromethane, dibromochloropropane and pyrene considered volatile for purposes of modeling (USEPA 2004).
Calculated based on spreadsheet provided with *User's Guide for the Johnson and Ettinger Indoor Air model (1991) for Subsurface Vapor Intrusion Into Buildings* (USEPA 2003) using
default input parameter values noted in Appendix 4 (see text for equations).
Indoor air screening levels listed only for volatile chemicals included in database of referenced model spreadsheet (plus MTBE).
URFs from Cal EPA DHS (Cal EPA 2001) where available (marked by "**") or otherwise as presented in referenced spreadseet (USEPA 2000). RfCs presented in spreadsheet or added as indicated in Appendix 4 (refer
to footnotes to VLOOKUP worksheet).
URF for TBA based on conversion of CSF presented in Table J.
Indoor air screening level for ethanol based on potential odor concerns (refer to Section 5.3.3 and Table H series).
50% Odor Recognition Thresholds from Massachusetts Department of Environmental Protection (MADEP, 1994) and ATSDR; included for reference (potential nuisance concerns, see Table H series).

TABLE F-1a. GROUNDWATER SCREENING LEVELS
(groundwater IS a current or potential drinking water resource)
(ug/l)

CHEMICAL PARAMETER	[1]Final Groundwater Screening Level	Basis	Ceiling Value (Taste & Odors, etc.) Table I-1	Drinking Water (Toxicity) Table F-3	Vapor Intrusion Into Buildings Table E-1a	Aquatic Habitat Goal (Chronic) Table F-4a
ACENAPHTHENE	2.0E+01	Ceiling Value	2.0E+01	4.2E+02	4.2E+03	2.3E+01
ACENAPHTHYLENE	3.0E+01	Aquatic Habitat Goal	2.0E+03	2.8E+02	(Use soil gas)	3.0E+01
ACETONE	1.5E+03	Aquatic Habitat Goal	2.0E+04	6.3E+03	5.3E-07	1.5E+03
ALDRIN	2.0E-03	Drinking Water Toxicity	8.5E+00	2.0E-03		1.3E-01
ANTHRACENE	7.3E-01	Aquatic Habitat Goal	2.2E+01	2.1E+03	4.3E-01	7.3E-01
ANTIMONY	6.0E+00	Drinking Water Toxicity	5.0E+04	6.0E+00		3.0E+01
ARSENIC	3.6E+01	Aquatic Habitat Goal	5.0E+04	5.0E+01		3.6E+01
BARIUM	1.0E+03	Drinking Water Toxicity	5.0E+04	1.0E+03		1.0E+03
BENZENE	1.0E+00	Drinking Water Toxicity	1.7E+02	1.0E+00	5.4E+02	4.6E+01
BENZO(a)ANTHRACENE	2.7E-02	Aquatic Habitat Goal	5.0E+00	2.9E-02		2.7E-02
BENZO(b)FLUORANTHENE	2.9E-02	Aquatic Habitat Goal	7.0E+00	2.9E-02		2.9E-02
BENZO(k)FLUORANTHENE	2.9E-02	Drinking Water Toxicity	4.0E-01	2.9E-02		3.7E+00
BENZO(g,h,i)PERYLENE	1.0E-01	Aquatic Habitat Goal	1.3E-01	2.8E+02		1.0E-01
BENZO(a)PYRENE	1.4E-02	Aquatic Habitat Goal	1.9E+00	2.0E-01		1.4E-02
BERYLLIUM	2.7E+00	Aquatic Habitat Goal	5.0E+04	4.0E+00		2.7E+00
BIPHENYL, 1,1-	5.0E-01	Ceiling Value	5.0E-01	3.5E+02	(Use soil gas)	1.4E+01
BIS(2-CHLOROETHYL)ETHER	1.4E-02	Drinking Water Toxicity	3.6E+02	1.4E-02	6.5E+01	6.1E+01
BIS(2-CHLOROISOPROPYL)ETHER	5.0E-01	Drinking Water Toxicity	3.2E+02	5.0E-01	(Use soil gas)	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	4.0E+00	Drinking Water Toxicity	6.5E+02	4.0E+00		3.2E-01
BORON	1.6E+00	Aquatic Habitat Goal	5.0E+04	1.0E+03		1.6E+00
BROMODICHLOROMETHANE	1.0E+02	Drinking Water Toxicity	5.0E+04	1.0E+02	1.7E+02	3.2E-03
BROMOFORM	1.0E+02	Drinking Water Toxicity	5.1E+02	1.0E+02		3.2E-03
BROMOMETHANE	9.8E+00	Drinking Water Toxicity	5.0E+04	9.8E+00	5.8E+02	1.6E+02
CADMIUM	1.1E+00	Aquatic Habitat Goal	5.0E+04	5.0E+00		1.1E+00
CARBON TETRACHLORIDE	5.0E-01	Drinking Water Toxicity	5.2E+02	5.0E-01	9.3E+00	9.8E+00
CHLORDANE	4.0E-03	Aquatic Habitat Goal	2.5E+00	1.0E-01		4.0E-03
CHLOROANILINE, p-	5.0E+00	Aquatic Habitat Goal	5.0E+04	2.8E-01		5.0E+00
CHLOROBENZENE	2.5E+01	Aquatic Habitat Goal	5.0E+01	7.0E-01	1.3E+04	2.5E-01
CHLOROETHANE	1.2E+01	Aquatic Habitat Goal	1.6E+01	1.2E-01	8.2E+02	1.2E-01
CHLOROFORM	7.0E+01	Drinking Water Toxicity	2.4E+03	7.0E-01	3.3E+02	6.2E-02
CHLOROMETHANE	1.3E+00	Drinking Water Toxicity	5.0E+04	1.3E+00	4.1E+01	3.2E-03
CHLOROPHENOL, 2-	1.8E-01	Ceiling Value	1.8E-01	3.5E-01	5.3E+03	4.4E-02
CHROMIUM (Total)	5.0E+01	Drinking Water Toxicity	5.0E+04	5.0E-01		1.8E+02
CHROMIUM III	1.8E+02	Aquatic Habitat Goal	5.0E+04	2.0E+05		1.8E+02
CHROMIUM VI	1.1E+01	Aquatic Habitat Goal	5.0E+04	2.1E+01		1.1E+01
CHRYSENE	2.9E-01	Drinking Water Toxicity	8.0E-01	2.9E-01	(Use soil gas)	3.5E-01
COBALT	3.0E+00	Aquatic Habitat Goal	5.0E+04	1.4E+02		3.0E+00
COPPER	3.1E+00	Aquatic Habitat Goal	1.0E+03	1.3E+03		3.1E+00

CHEMICAL PARAMETER	[1]Final Groundwater Screening Level	Basis	Ceiling Value (Taste & Odors, etc.) Table I-1	Drinking Water (Toxicity) Table F-3	Vapor Intrusion Into Buildings Table E-1a	Aquatic Habitat Goal (Chronic) Table F-4a
CYANIDE (Free)	1.0E+00	Aquatic Habitat Goal	1.7E+02	2.0E+02	(Use soil gas)	1.0E+00
DIBENZO(a,h)ANTHTRACENE	8.5E-03	Drinking Water Toxicity	2.5E-01	8.5E-03		7.5E+00
DIBROMOCHLOROMETHANE	1.0E+02	Drinking Water Toxicity	5.0E+04	1.0E+02	1.7E+02	3.2E-03
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-01	Aquatic Habitat Goal	1.0E+01	2.0E-01	(Use soil gas)	2.0E-01
DIBROMOETHANE, 1,2-	5.0E-02	Drinking Water Toxicity	5.0E+04	5.0E-02	1.5E+02	1.4E-03
DICHLOROBENZENE, 1,2-	1.0E+01	Ceiling Value	1.0E+01	6.0E+02	7.7E+04	1.4E+01
DICHLOROBENZENE, 1,3-	6.5E+01	Aquatic Habitat Goal	5.0E+04	2.1E+02	(Use soil gas)	6.5E+01
DICHLOROBENZENE, 1,4-	5.0E+00	Ceiling Value	5.0E+00	5.0E+00	3.4E+02	1.5E+01
DICHLOROBENZIDINE, 3,3-	2.9E-02	Drinking Water Toxicity	1.6E+03	2.9E-02		2.5E+02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.0E-03	Aquatic Habitat Goal	8.0E+01	1.5E-01		1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.0E-03	Aquatic Habitat Goal	2.0E+01	1.0E-01		1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.0E-03	Aquatic Habitat Goal	1.5E+00	1.0E-01		1.0E-03
DICHLOROETHANE, 1,1-	5.0E+00	Drinking Water Toxicity	5.0E+04	5.0E+00	1.0E+03	4.7E+01
DICHLOROETHANE, 1,2-	5.0E-01	Drinking Water Toxicity	7.0E+03	5.0E-01	2.0E+02	1.0E+04
DICHLOROETHYLENE, 1,1-	6.0E+00	Drinking Water Toxicity	1.5E+03	6.0E+00	6.3E+03	2.5E+01
DICHLOROETHYLENE, Cis 1,2-	6.0E+00	Drinking Water Toxicity	5.0E+04	6.0E+00	6.2E+03	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	1.0E+01	Drinking Water Toxicity	2.6E+02	1.0E+01	6.7E+03	5.9E+02
DICHLOROPHENOL, 2,4-	3.0E-01	Ceiling Value	3.0E-01	2.1E+01		1.8E+02
DICHLOROPROPANE, 1,2-	5.0E+00	Drinking Water Toxicity	1.0E+01	5.0E+00	2.8E+02	1.5E+03
DICHLOROPROPENE, 1,3-	5.0E-01	Drinking Water Toxicity	5.0E+04	5.0E-01	5.3E+01	1.2E+02
DIELDRIN	1.9E-03	Aquatic Habitat Goal	4.1E+01	2.2E-03		1.9E-03
DIETHYLPHTHALATE	1.5E+00	Aquatic Habitat Goal	5.0E+04	5.6E+03		1.5E+00
DIMETHYLPHTHALATE	1.5E+00	Aquatic Habitat Goal	5.0E+04	7.0E+04		1.5E+00
DIMETHYLPHENOL, 2,4-	1.0E+02	Drinking Water Toxicity	4.0E+02	1.0E+02	2.5E-06	1.1E+02
DINITROPHENOL, 2,4-	1.4E+01	Drinking Water Toxicity	5.0E+04	1.4E+01		7.5E+01
DINITROTOLUENE, 2,4-	1.1E-01	Drinking Water Toxicity	5.0E+04	1.1E-01		1.2E+02
1,4 DIOXANE	3.0E+00	Drinking Water Toxicity	5.0E+04	3.0E+00		3.4E+05
DIOXIN (2,3,7,8-TCDD)	5.0E-06	Aquatic Habitat Goal	7.0E+03	3.0E-05		5.0E-06
ENDOSULFAN	8.7E-03	Aquatic Habitat Goal	7.5E+01	4.2E+01		8.7E-03
ENDRIN	2.3E-03	Aquatic Habitat Goal	4.1E+01	2.0E+00		2.3E-03
ETHANOL	5.0E+04	Ceiling Value	5.0E+04			
ETHYLBENZENE	3.0E+01	Ceiling Value	3.0E+01	7.0E+02	1.7E+05	2.9E+02
FLUORANTHENE	8.0E+00	Aquatic Habitat Goal	1.3E+02	2.8E+02		8.0E+00
FLUORENE	3.9E+00	Aquatic Habitat Goal	9.5E+02	2.8E+02	1.9E+03	3.9E+00
HEPTACHLOR	3.8E-03	Aquatic Habitat Goal	2.0E+01	1.0E-02		3.8E-03
HEPTACHLOR EPOXIDE	3.8E-03	Aquatic Habitat Goal	1.8E+02	1.0E-02		3.8E-03
HEXACHLOROBENZENE	1.0E+00	Drinking Water Toxicity	5.5E+01	1.0E+00		3.7E+00
HEXACHLOROBUTADIENE	2.1E-01	Drinking Water Toxicity	6.0E+00	2.1E-01		4.7E+00

TABLE F-1a. GROUNDWATER SCREENING LEVELS
(groundwater IS a current or potential drinking water resource)
(ug/l)

CHEMICAL PARAMETER	[1] Final Groundwater Screening Level	Basis	Ceiling Value (Taste & Odors, etc.) Table I-1	Drinking Water (Toxicity) Table F-3	Vapor Intrusion Into Buildings Table E-1a	Aquatic Habitat Goal (Chronic) Table F-4a
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	8.0E-02	Aquatic Habitat Goal	3.5E+03	2.0E-01		8.0E-02
HEXACHLOROETHANE	7.0E-01	Drinking Water Toxicity	1.0E+01	7.0E-01		1.2E+01
INDENO(1,2,3-cd)PYRENE	2.9E-02	Aquatic Habitat Goal	2.7E-01	2.9E-02		2.9E-02
LEAD	2.5E+00	Aquatic Habitat Goal	5.0E+04	1.5E+01		2.5E+00
MERCURY	1.2E-02	Aquatic Habitat Goal	5.0E+04	2.0E+00	(Use soil gas)	1.2E-02
METHOXYCHLOR	1.9E-02	Aquatic Habitat Goal	2.0E+01	4.0E+01		1.9E-02
METHYLENE CHLORIDE	5.0E+00	Drinking Water Toxicity	9.1E+03	5.0E+00	2.4E+03	2.2E+03
METHYL ETHYL KETONE	4.2E+03	Drinking Water Toxicity	8.4E+03	4.2E+03	2.4E+07	1.4E+04
METHYL ISOBUTYL KETONE	1.2E+02	Drinking Water Toxicity	1.3E+03	1.2E+02	3.0E+06	1.7E+02
METHYL MERCURY	3.0E-03	Aquatic Habitat Goal	5.0E+04	7.0E-02		3.0E-03
METHYLNAPHTHALENE (total 1- & 2-)	2.1E+00	Aquatic Habitat Goal	1.0E+01	2.8E+02	2.6E-04	2.1E+00
METHYL TERT BUTYL ETHER	5.0E+00	Ceiling Value	5.0E+00	1.3E+01	2.4E+04	8.0E+03
MOLYBDENUM	3.5E+01	Drinking Water Toxicity	5.0E+04	3.5E+01		2.4E+02
NAPHTHALENE	1.7E+01	Drinking Water Toxicity	2.1E+01	1.7E+01	3.2E+03	2.4E+01
NICKEL	8.2E+00	Aquatic Habitat Goal	5.0E+04	1.0E+02		8.2E+00
PENTACHLOROPHENOL	1.0E+00	Drinking Water Toxicity	3.0E+01	1.0E+00		7.9E+00
PERCHLORATE	6.0E+00	Drinking Water Toxicity	5.0E+04	6.0E+00		6.0E-02
PHENANTHRENE	4.6E+00	Aquatic Habitat Goal	4.1E+02	2.8E+02	(Use soil gas)	4.6E+00
PHENOL	5.0E+00	Ceiling Value	5.0E+00	4.2E+03		1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	1.4E-02	Aquatic Habitat Goal	1.6E+01	5.0E-01		1.4E-02
PYRENE	2.0E+00	Aquatic Habitat Goal	6.8E+01	2.1E+02	1.4E+02	2.0E+00
SELENIUM	5.0E+00	Aquatic Habitat Goal	5.0E+04	5.0E+01		5.0E+00
SILVER	1.9E-01	Aquatic Habitat Goal	1.0E+02	1.0E+02		1.9E-01
STYRENE	1.0E+01	Ceiling Value	1.0E+01	1.0E+02	3.1E+05	1.0E+02
tert-BUTYL ALCOHOL	1.2E+01	Drinking Water Toxicity	5.0E+04	1.2E+01	(Use soil gas)	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	1.3E+00	Drinking Water Toxicity	5.0E+04	1.3E+00	(Use soil gas)	9.3E+02
TETRACHLOROETHANE, 1,1,2,2-	1.0E+00	Drinking Water Toxicity	5.0E+02	1.0E+00	1.9E+02	4.2E+02
TETRACHLOROETHYLENE	5.0E+00	Drinking Water Toxicity	1.7E+02	5.0E+00	1.2E+02	1.2E+02
THALLIUM	2.0E+00	Drinking Water Toxicity	5.0E+04	2.0E+00		2.0E+01
TOLUENE	4.0E+01	Ceiling Value	4.0E+01	1.5E+02	3.8E+05	1.3E+02
TOXAPHENE	2.0E-04	Aquatic Habitat Goal	1.4E+02	3.0E+00		2.0E-04
TPH (gasolines)	1.0E+02	Ceiling Value	1.0E+02	2.1E+02	(Use soil gas)	5.0E+02
TPH (middle distillates)	1.0E+02	Ceiling Value	1.0E+02	2.1E+02	(Use soil gas)	6.4E+02
TPH (residual fuels)	1.0E+02	Ceiling Value	1.0E+02	2.1E+02		6.4E+02
TRICHLOROBENZENE, 1,2,4-	2.5E+01	Aquatic Habitat Goal	3.0E+03	7.0E-01	2.5E+03	2.5E+01
TRICHLOROETHANE, 1,1,1-	6.2E+01	Aquatic Habitat Goal	9.7E+02	2.0E+02	1.3E+05	6.2E+01
TRICHLOROETHANE, 1,1,2-	5.0E+00	Drinking Water Toxicity	5.0E+04	5.0E+00	3.5E+02	4.7E+03
TRICHLOROETHYLENE	5.0E+00	Drinking Water Toxicity	3.1E+02	5.0E+00	5.3E+02	3.6E+02

TABLE F-1a. GROUNDWATER SCREENING LEVELS
(groundwater IS a current or potential drinking water resource)
(ug/l)

CHEMICAL PARAMETER	[1]Final Groundwater Screening Level	Basis	Ceiling Value (Taste & Odors, etc.) Table I-1	Drinking Water (Toxicity) Table F-3	Vapor Intrusion Into Buildings Table E-1a	Aquatic Habitat Goal (Chronic) Table F-4a
TRICHLOROPHENOL, 2,4,5-	1.1E+01	Aquatic Habitat Goal	2.0E+02	7.0E+02	8.3E+05	1.1E+01
TRICHLOROPHENOL, 2,4,6-	5.0E-01	Drinking Water Toxicity	1.0E+02	5.0E-01		4.9E+02
VANADIUM	1.5E+01	Drinking Water Toxicity	5.0E+04	1.5E+01		1.9E+01
VINYL CHLORIDE	5.0E-01	Drinking Water Toxicity	3.4E+03	5.0E-01	3.8E+00	7.8E+02
XYLENES	2.0E+01	Ceiling Value	2.0E+01	1.8E+03	1.6E+05	1.0E+02
ZINC	8.1E+01	Aquatic Habitat Goal	5.0E+03	5.0E+03		8.1E+01

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Lowest of Ceiling Value, Drinking Water (toxicity) goal, Indoor-Air Impact goal and Aquatic Habitat Goal>Used to develop soil leaching levels for protection of groundwater quality.

TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

sol - solubility threshold

Ceiling Level: Odor threshold, 1/2 solubility or 50000 ug/L maximum, whichever is lower. Intended to limit general groundwater resource degradation.

Odor-thresholds assume no dilution.

Human Toxicity: Based on primary maximum concentration levels (MCLs), or equivalent. Considered protective of human health.

Indoor Air Impact: Addresses potential emission of volatile chemicals from groundwater and subsequent impact on indoor air. Value for very permeable (e.g., sandy vadose-zone soils).

Aquatic Habitat Goal: Addresses potential discharge of groundwater to surface waterbody and subsequent impact on aquatic life; Potential dilution upon discharge to surface water not considered.

Review of aquatic ecotoxicty data for ethanol underway. Based on preliminary review of available data, chronic toxicity screening levels likely to be significantly greater than ceiling level of 50,000 ug/L (refer to USEPA 2003b, ECOTOX database).

Method detection limits and background concentrations replace final screening level as appropriate.

TABLE F-1b. GROUNDWATER SCREENING LEVELS
(groundwater IS NOT a current or potential drinking water resource)
(ug/l)

CHEMICAL PARAMETER	[1]Final Groundwater Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-2	Vapor Intrusion Into Buildings Table E-1a	Estuary Aquatic Habitat Goal (Chronic) Table F-4a
ACENAPHTHENE	2.3E+01	Aquatic Habitat Goal	2.0E-02	4.2E+03	2.3E+01
ACENAPHTHYLENE	3.0E-01	Aquatic Habitat Goal	2.0E+03	(Use soil gas)	3.0E+01
ACETONE	1.5E-03	Aquatic Habitat Goal	5.0E+04	5.3E+07	1.5E+03
ALDRIN	1.3E-01	Aquatic Habitat Goal	8.5E+00		1.3E-01
ANTHRACENE	7.3E-01	Aquatic Habitat Goal	2.2E-01	4.3E+01	7.3E-01
ANTIMONY	3.0E+01	Aquatic Habitat Goal	5.0E+04		3.0E+01
ARSENIC	3.6E+01	Aquatic Habitat Goal	5.0E+04		3.6E+01
BARIUM	1.0E+03	Aquatic Habitat Goal	5.0E+04		1.0E+03
BENZENE	4.6E+01	Aquatic Habitat Goal	2.0E+04	5.4E+02	4.6E+01
BENZO(a)ANTHRACENE	2.7E-02	Aquatic Habitat Goal	5.0E+00		2.7E-02
BENZO(b)FLUORANTHENE	2.9E-02	Aquatic Habitat Goal	7.0E+00		2.9E-02
BENZO(k)FLUORANTHENE	4.0E-01	Ceiling Value	4.0E-01		3.7E+00
BENZO(g,h,i)PERYLENE	1.0E-01	Aquatic Habitat Goal	1.3E-01		1.0E-01
BENZO(a)PYRENE	1.4E-02	Aquatic Habitat Goal	1.9E+00		1.4E-02
BERYLLIUM	2.7E+00	Aquatic Habitat Goal	5.0E+04		2.7E+00
BIPHENYL, 1,1-	5.0E+00	Ceiling Value	5.0E+00	(Use soil gas)	1.4E+01
BIS(2-CHLOROETHYL)ETHER	6.1E+01	Aquatic Habitat Goal	3.6E+03	6.5E+01	6.1E+01
BIS(2-CHLOROISOPROPYL)ETHER	6.1E+01	Aquatic Habitat Goal	3.2E+03	(Use soil gas)	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	3.2E-01	Aquatic Habitat Goal	6.5E+02		3.2E+01
BORON	1.6E+00	Aquatic Habitat Goal	5.0E+04		1.6E+00
BROMODICHLOROMETHANE	1.7E-02	Indoor Air Impacts	5.0E+04	1.7E+02	3.2E+03
BROMOFORM	3.2E+03	Aquatic Habitat Goal	5.1E+03		3.2E+03
BROMOMETHANE	1.6E+02	Aquatic Habitat Goal	5.0E+04	5.8E+02	1.6E+02
CADMIUM	1.1E+00	Aquatic Habitat Goal	5.0E+04		1.1E+00
CARBON TETRACHLORIDE	9.3E+00	Indoor Air Impacts	5.2E+03	9.3E+00	9.8E+00
CHLORDANE	4.0E-03	Aquatic Habitat Goal	2.5E+01		4.0E-03
CHLOROANILINE, p-	5.0E+00	Aquatic Habitat Goal	5.0E+04		5.0E+00
CHLOROBENZENE	2.5E+01	Aquatic Habitat Goal	5.0E+02	1.3E+04	2.5E+01
CHLOROETHANE	1.2E+01	Aquatic Habitat Goal	1.6E+02	8.2E+02	1.2E+01
CHLOROFORM	3.3E+02	Indoor Air Impacts	2.4E+04	3.3E+02	6.2E+02
CHLOROMETHANE	4.1E+01	Indoor Air Impacts	5.0E+04	4.1E+01	3.2E+03
CHLOROPHENOL, 2-	1.8E+00	Ceiling Value	1.8E+00	5.3E+03	4.4E+02
CHROMIUM (Total)	1.8E+02	Aquatic Habitat Goal	5.0E+04		1.8E+02
CHROMIUM III	1.8E+02	Aquatic Habitat Goal	5.0E+04		1.8E+02
CHROMIUM VI	1.1E+01	Aquatic Habitat Goal	5.0E+04		1.1E+01
CHRYSENE	3.5E-01	Aquatic Habitat Goal	8.0E-01	(Use soil gas)	3.5E-01
COBALT	3.0E+00	Aquatic Habitat Goal	5.0E+04		3.0E+00
COPPER	3.1E+00	Aquatic Habitat Goal	5.0E+04		3.1E+00

TABLE F-1b. GROUNDWATER SCREENING LEVELS
(groundwater IS NOT a current or potential drinking water resource)
(ug/l)

CHEMICAL PARAMETER	¹Final Groundwater Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-2	Vapor Intrusion Into Buildings Table E-1a	Estuary Aquatic Habitat Goal (Chronic) Table F-4a
CYANIDE (Free)	1.0E+00	Aquatic Habitat Goal	1.7E+03	(Use soil gas)	1.0E+00
DIBENZO(a,h)ANTHTRACENE	2.5E-01	Ceiling Value	2.5E-01		7.5E+00
DIBROMOCHLOROMETHANE	1.7E+02	Indoor Air Impacts	5.0E+04	1.7E+02	3.2E+03
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-01	Aquatic Habitat Goal	1.0E+02	(Use soil gas)	2.0E-01
DIBROMOETHANE, 1,2-	1.5E+02	Indoor Air Impacts	5.0E+04	1.5E+02	1.4E+03
DICHLOROBENZENE, 1,2-	1.4E+01	Aquatic Habitat Goal	1.0E+02	7.7E+04	1.4E+01
DICHLOROBENZENE, 1,3-	6.5E+01	Aquatic Habitat Goal	5.0E+04	(Use soil gas)	6.5E+01
DICHLOROBENZENE, 1,4-	1.5E+01	Aquatic Habitat Goal	1.1E+02	3.4E+02	1.5E+01
DICHLOROBENZIDINE, 3,3-	2.5E+02	Aquatic Habitat Goal	1.6E+03		2.5E+02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.0E-03	Aquatic Habitat Goal	8.0E+01		1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.0E-03	Aquatic Habitat Goal	2.0E+01		1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.0E-03	Aquatic Habitat Goal	1.5E+00		1.0E-03
DICHLOROETHANE, 1,1-	4.7E+01	Aquatic Habitat Goal	5.0E+04	1.0E+03	4.7E+01
DICHLOROETHANE, 1,2-	2.0E+02	Indoor Air Impacts	5.0E+04	2.0E+02	1.0E+04
DICHLOROETHYLENE, 1,1-	2.5E+01	Aquatic Habitat Goal	1.5E+04	6.3E+03	2.5E+01
DICHLOROETHYLENE, Cis 1,2-	5.9E+02	Aquatic Habitat Goal	5.0E+04	6.2E+03	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	5.9E+02	Aquatic Habitat Goal	2.6E+03	6.7E+03	5.9E+02
DICHLOROPHENOL, 2,4-	3.0E+00	Ceiling Value	3.0E+00		1.8E+02
DICHLOROPROPANE, 1,2-	1.0E+02	Ceiling Value	1.0E+02	2.8E+02	1.5E+03
DICHLOROPROPENE, 1,3-	5.3E+01	Indoor Air Impacts	5.0E+04	5.3E+01	1.2E+02
DIELDRIN	1.9E-03	Aquatic Habitat Goal	9.3E+01		1.9E-03
DIETHYLPHTHALATE	1.5E+00	Aquatic Habitat Goal	5.0E+04		1.5E+00
DIMETHYLPHTHALATE	1.5E+00	Aquatic Habitat Goal	5.0E+04		1.5E+00
DIMETHYLPHENOL, 2,4-	1.1E+02	Aquatic Habitat Goal	4.0E+03	2.5E+06	1.1E+02
DINITROPHENOL, 2,4-	7.5E+01	Aquatic Habitat Goal	5.0E+04		7.5E+01
DINITROTOLUENE, 2,4-	1.2E+02	Aquatic Habitat Goal	5.0E+04		1.2E+02
1,4 DIOXANE	5.0E+04	Ceiling Value	5.0E+04		3.4E+05
DIOXIN (2,3,7,8-TCDD)	5.0E-06	Aquatic Habitat Goal	7.0E-03		5.0E-06
ENDOSULFAN	8.7E-03	Aquatic Habitat Goal	7.5E+01		8.7E-03
ENDRIN	2.3E-03	Aquatic Habitat Goal	1.3E+02		2.3E-03
ETHANOL	5.0E+04	Ceiling Value	5.0E+04		
ETHYLBENZENE	2.9E+02	Aquatic Habitat Goal	3.0E+02	1.7E+05	2.9E+02
FLUORANTHENE	8.0E+00	Aquatic Habitat Goal	1.3E+02		8.0E+00
FLUORENE	3.9E+00	Aquatic Habitat Goal	9.5E+02	1.9E+03	3.9E+00
HEPTACHLOR	3.8E-03	Aquatic Habitat Goal	2.8E+01		3.8E-03
HEPTACHLOR EPOXIDE	3.8E-03	Aquatic Habitat Goal	1.8E+02		3.8E-03
HEXACHLOROBENZENE	3.7E+00	Aquatic Habitat Goal	5.5E+01		3.7E+00
HEXACHLOROBUTADIENE	4.7E+00	Aquatic Habitat Goal	6.0E+01		4.7E+00

TABLE F-1b. GROUNDWATER SCREENING LEVELS
(groundwater IS NOT a current or potential drinking water resource)
(ug/l)

CHEMICAL PARAMETER	'Final Groundwater Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-2	Vapor Intrusion Into Buildings Table E-1a	Estuary Aquatic Habitat Goal (Chronic) Table F-4a
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	8.0E-02	Aquatic Habitat Goal	3.5E+03		8.0E-02
HEXACHLOROETHANE	1.2E+01	Aquatic Habitat Goal	1.0E+02		1.2E+01
INDENO(1,2,3-cd)PYRENE	2.9E-02	Aquatic Habitat Goal	2.7E-01		2.9E-02
LEAD	2.5E+00	Aquatic Habitat Goal	5.0E+04		2.5E+00
MERCURY	1.2E-02	Aquatic Habitat Goal	5.0E+04	(Use soil gas)	1.2E-02
METHOXYCHLOR	1.9E-02	Aquatic Habitat Goal	2.0E+01		1.9E-02
METHYLENE CHLORIDE	2.2E+03	Aquatic Habitat Goal	5.0E+04	2.4E+03	2.2E+03
METHYL ETHYL KETONE	1.4E+04	Aquatic Habitat Goal	5.0E+04	2.4E+07	1.4E+04
METHYL ISOBUTYL KETONE	1.7E+02	Aquatic Habitat Goal	1.3E+04	3.0E+06	1.7E+02
METHYL MERCURY	3.0E-03	Aquatic Habitat Goal	5.0E+04		3.0E-03
METHYLNAPHTHALENE (total 1- & 2-)	2.1E+00	Aquatic Habitat Goal	1.0E+02	2.6E+04	2.1E+00
METHYL TERT BUTYL ETHER	1.8E+03	Ceiling Value	1.8E+03	2.4E+04	8.0E+03
MOLYBDENUM	2.4E+02	Aquatic Habitat Goal	5.0E+04		2.4E+02
NAPHTHALENE	2.4E+01	Aquatic Habitat Goal	2.1E+02	3.2E+03	2.4E+01
NICKEL	8.2E+00	Aquatic Habitat Goal	5.0E+04		8.2E+00
PENTACHLOROPHENOL	7.9E+00	Aquatic Habitat Goal	5.9E+03		7.9E+00
PERCHLORATE	6.0E+02	Aquatic Habitat Goal	5.0E+04		6.0E+02
PHENANTHRENE	4.6E+00	Aquatic Habitat Goal	4.1E+02	(Use soil gas)	4.6E+00
PHENOL	1.3E+03	Aquatic Habitat Goal	5.0E+04		1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	1.4E-02	Aquatic Habitat Goal	1.6E+01		1.4E-02
PYRENE	2.0E+00	Aquatic Habitat Goal	6.8E+01	1.4E+02	2.0E+00
SELENIUM	5.0E+00	Aquatic Habitat Goal	5.0E+04		5.0E+00
SILVER	1.9E-01	Aquatic Habitat Goal	5.0E+04		1.9E-01
STYRENE	1.0E+02	Aquatic Habitat Goal	1.1E+02	3.1E+05	1.0E+02
tert-BUTYL ALCOHOL	1.8E+04	Aquatic Habitat Goal	5.0E+04	(Use soil gas)	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	9.3E+02	Aquatic Habitat Goal	5.0E+04	(Use soil gas)	9.3E+02
TETRACHLOROETHANE, 1,1,2,2-	1.9E+02	Indoor Air Impacts	5.0E+03	1.9E+02	4.2E+02
TETRACHLOROETHYLENE	1.2E+02	Aquatic Habitat Goal	3.0E+03	1.2E+02	1.2E+02
THALLIUM	2.0E+01	Aquatic Habitat Goal	5.0E+04		2.0E+01
TOLUENE	1.3E+02	Aquatic Habitat Goal	4.0E+02	3.8E+05	1.3E+02
TOXAPHENE	2.0E-04	Aquatic Habitat Goal	1.4E+02		2.0E-04
TPH (gasolines)	5.0E+02	Aquatic Habitat Goal	5.0E+03	(Use soil gas)	5.0E+02
TPH (middle distillates)	6.4E+02	Aquatic Habitat Goal	2.5E+03	(Use soil gas)	6.4E+02
TPH (residual fuels)	6.4E+02	Aquatic Habitat Goal	2.5E+03		6.4E+02
TRICHLOROBENZENE, 1,2,4-	2.5E+01	Aquatic Habitat Goal	3.0E+04	2.5E+03	2.5E+01
TRICHLOROETHANE, 1,1,1-	6.2E+01	Aquatic Habitat Goal	5.0E+04	1.3E+05	6.2E+01
TRICHLOROETHANE, 1,1,2-	3.5E+02	Indoor Air Impacts	5.0E+04	3.5E+02	4.7E+03
TRICHLOROETHYLENE	3.6E+02	Aquatic Habitat Goal	5.0E+04	5.3E+02	3.6E+02

TABLE F-1b. GROUNDWATER SCREENING LEVELS
(groundwater IS NOT a current or potential drinking water resource)
(ug/l)

CHEMICAL PARAMETER	¹Final Groundwater Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-2	Vapor Intrusion Into Buildings Table E-1a	Estuary Aquatic Habitat Goal (Chronic) Table F-4a
TRICHLOROPHENOL, 2,4,5-	1.1E+01	Aquatic Habitat Goal	2.0E+03	8.3E+05	1.1E+01
TRICHLOROPHENOL, 2,4,6-	4.9E+02	Aquatic Habitat Goal	1.0E+03		4.9E+02
VANADIUM	1.9E+01	Aquatic Habitat Goal	5.0E+04		1.9E+01
VINYL CHLORIDE	3.8E+00	Indoor Air Impacts	3.4E+04	3.8E+00	7.8E+02
XYLENES	1.0E+02	Aquatic Habitat Goal	5.3E+03	1.6E+05	1.0E+02
ZINC	8.1E+01	Aquatic Habitat Goal	5.0E+04		8.1E+01

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Lowest of groundwater Ceiling Value, Indoor-Air Impact goal and Aquatic Habitat Goal. Used to develop soil leaching levels for protection of groundwater quality.

NV: No Value. Use of soil gas screening levels recommended for chemicals with inadequate physio-chemical constant data for groundwater models.

TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

sol - solubility threshold

Category includes groundwater that does not meet drinking water quality requirements under natural conditions (e.g., excessive total dissolved solids) AND/OR situated in strata that lack adequate aquifer characteristics AND is not likely to otherwise directly impact a source of drinking water.

Ceiling Level: Odor threshold, 1/2 solubility or 50000 ug/L maximum, whichever is lower. Intended to limit general groundwater resource degradation.

Odor-thresholds assume ten-fold dilution of groundwater upon mixing with surface water.

Indoor Air Impact: Addresses potential emission of volatile chemicals from groundwater and subsequent impact on indoor air. Value for very permeable (e.g., coarse-grained soils).

Aquatic Life Protection: Addresses potential discharge of groundwater to surface waterbody and subsequent impact on aquatic life; screening levels assume no dilution upon discharge to surface water unless otherwise noted.

Review of aquatic ecotoxicty data for ethanol underway. Based on preliminary review of available data, chronic toxicity screening levels likely to be significantly greater than ceiling level of 50,000 ug/L (refer to USEPA 2003b, ECOTOX database).

Method detection limits and background concentrations replace final screening level as appropriate.

TABLE F-2a. SURFACE WATER SCREENING LEVELS
Fresh Water Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Ceiling Value (Taste & Odors, etc.) Table I-3	Drinking Water (Toxicity) Table F-3	Fresh Water Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
ACENAPHTHENE	2.0E+01	Ceiling Value	2.0E-01	4.2E+02	2.3E+01	2.7E+03
ACENAPHTHYLENE	3.0E+01	Aquatic Habitat Chronic Toxicity	2.0E-03	2.8E+02	3.0E+01	
ACETONE	1.5E+03	Aquatic Habitat Chronic Toxicity	2.0E-04	6.3E+03	1.5E+03	
ALDRIN	1.4E-04	Bioaccumulation/Human Consumption	8.5E+00	2.0E-03	3.0E-01	1.4E-04
ANTHRACENE	7.3E-01	Aquatic Habitat Chronic Toxicity	2.2E-01	2.1E+03	7.3E-01	1.1E+05
ANTIMONY	6.0E+00	Drinking Water Toxicity	5.0E+04	6.0E+00	3.0E+01	4.3E+03
ARSENIC	1.4E-01	Bioaccumulation/Human Consumption	5.0E+04	5.0E+01	1.5E+02	1.4E-01
BARIUM	1.0E+03	Drinking Water Toxicity	5.0E+04	1.0E+03	1.0E+03	
BENZENE	1.0E+00	Drinking Water Toxicity	1.7E+02	1.0E+00	4.6E+01	7.1E+01
BENZO(a)ANTHRACENE	2.7E-02	Aquatic Habitat Chronic Toxicity	5.0E+00	2.9E-02	2.7E-02	4.9E-02
BENZO(b)FLUORANTHENE	2.9E-02	Drinking Water Toxicity	7.0E+00	2.9E-02	2.9E-02	4.9E-02
BENZO(k)FLUORANTHENE	2.9E-02	Drinking Water Toxicity	4.0E-01	2.9E-02	3.7E+00	4.9E-02
BENZO(g,h,i)PERYLENE	1.0E-01	Aquatic Habitat Chronic Toxicity	1.3E-01	2.8E+02	1.0E-01	
BENZO(a)PYRENE	1.4E-02	Aquatic Habitat Chronic Toxicity	1.9E+00	2.0E-01	1.4E-02	4.9E-02
BERYLLIUM	2.7E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	4.0E+00	2.7E+00	
BIPHENYL, 1,1-	5.0E-01	Ceiling Value	5.0E-01	3.5E+02	1.4E+01	
BIS(2-CHLOROETHYL)ETHER	1.4E-02	Drinking Water Toxicity	3.6E+02	1.4E-02	6.1E+01	1.4E+00
BIS(2-CHLOROISOPROPYL)ETHER	5.0E-01	Drinking Water Toxicity	3.2E+02	5.0E-01	6.1E+01	1.7E+05
BIS(2-ETHYLHEXYL)PHTHALATE	4.0E+00	Drinking Water Toxicity	6.5E+02	4.0E+00	3.2E+01	5.9E+00
BORON	1.6E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.0E+03	1.6E+00	
BROMODICHLOROMETHANE	1.0E+02	Drinking Water Toxicity	5.0E+04	1.0E+02	3.2E+03	
BROMOFORM	1.0E+02	Drinking Water Toxicity	5.1E+02	1.0E+02	3.2E+03	3.6E+02
BROMOMETHANE	9.8E+00	Drinking Water Toxicity	5.0E+04	9.8E+00	1.6E+02	4.0E+03
CADMIUM	1.1E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	5.0E+00	1.1E+00	
CARBON TETRACHLORIDE	5.0E-01	Drinking Water Toxicity	5.2E+02	5.0E-01	9.8E+00	4.4E+00
CHLORDANE	5.9E-04	Bioaccumulation/Human Consumption	2.5E+00	1.0E-01	4.3E-03	5.9E-04
CHLOROANILINE, p-	5.0E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	2.8E-01	5.0E+00	
CHLOROBENZENE	2.5E+01	Aquatic Habitat Chronic Toxicity	5.0E+01	7.0E+01	2.5E+01	2.1E+04
CHLOROETHANE	1.2E+01	Drinking Water Toxicity	1.6E+01	1.2E-01	1.2E+01	
CHLOROFORM	7.0E+01	Drinking Water Toxicity	2.4E+03	7.0E+01	6.2E+02	4.7E+02
CHLOROMETHANE	1.3E+00	Drinking Water Toxicity	5.0E+04	1.3E+00	3.2E+03	
CHLOROPHENOL, 2-	1.8E-01	Ceiling Value	1.8E-01	3.5E+01	4.4E+02	4.0E+02
CHROMIUM (Total)	5.0E+01	Drinking Water Toxicity	5.0E+04	5.0E+01	1.8E+02	
CHROMIUM III	1.8E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	2.0E+05	1.8E+02	
CHROMIUM VI	1.1E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	2.1E+01	1.1E+01	
CHRYSENE	4.9E-02	Bioaccumulation/Human Consumption	8.0E-01	2.9E-01	3.5E-01	4.9E-02

TABLE F-2a. SURFACE WATER SCREENING LEVELS
Fresh Water Habitats
(ug/l)

CHEMICAL PARAMETER	Final Surface Water Screening Level[1]	Basis	Ceiling Value (Taste & Odors, etc.) Table I-3	Drinking Water (Toxicity) Table F-3	Fresh Water Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
COBALT	3.0E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.4E+02	3.0E+00	
COPPER	9.0E+00	Aquatic Habitat Chronic Toxicity	1.0E+03	1.3E+03	9.0E+00	
CYANIDE (Free)	5.2E+00	Aquatic Habitat Chronic Toxicity	1.7E-02	2.0E+02	5.2E+00	2.2E+05
DIBENZO(a,h)ANTHRACENE	8.5E-03	Drinking Water Toxicity	2.5E-01	8.5E-03	7.5E+00	4.9E-02
DIBROMOCHLOROMETHANE	4.6E+01	Bioaccumulation/Human Consumption	5.0E+04	1.0E+02	3.2E+03	4.6E+01
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-01	Drinking Water Toxicity	1.0E-01	2.0E-01	2.0E-01	
DIBROMOETHANE, 1,2-	5.0E-02	Drinking Water Toxicity	5.0E-04	5.0E-02	1.4E+03	
DICHLOROBENZENE, 1,2-	1.0E+01	Ceiling Value	1.0E+01	6.0E+02	1.4E+01	1.7E+04
DICHLOROBENZENE, 1,3-	7.1E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	2.1E+02	7.1E+01	2.6E+03
DICHLOROBENZENE, 1,4-	5.0E+00	Ceiling Value, Drinking Water Toxicity	5.0E+00	5.0E+00	1.5E+01	2.6E+03
DICHLOROBENZIDINE, 3,3-	2.9E-02	Drinking Water Toxicity	1.6E-03	2.9E-02	2.5E+02	7.7E-02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.4E-04	Bioaccumulation/Human Consumption	8.0E-01	1.5E-01	1.0E-03	8.4E-04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	5.9E-04	Bioaccumulation/Human Consumption	2.0E-01	1.0E-01	1.0E-03	5.9E-04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	5.9E-04	Bioaccumulation/Human Consumption	1.5E+00	1.0E-01	1.0E-03	5.9E-04
DICHLOROETHANE, 1,1-	5.0E+00	Drinking Water Toxicity	5.0E+04	5.0E+00	4.7E+01	9.9E+01
DICHLOROETHANE, 1,2-	5.0E-01	Drinking Water Toxicity	7.0E-03	5.0E-01	1.0E+04	3.2E+00
DICHLOROETHYLENE, 1,1-	3.2E+00	Bioaccumulation/Human Consumption	1.5E-03	6.0E+00	2.5E+01	
DICHLOROETHYLENE, Cis 1,2-	6.0E+00	Drinking Water Toxicity	5.0E+04	6.0E+00	5.9E+02	140000
DICHLOROETHYLENE, Trans 1,2-	1.0E+01	Drinking Water Toxicity	2.6E-02	1.0E+01	5.9E+02	7.9E+02
DICHLOROPHENOL, 2,4-	3.0E-01	Ceiling Value	3.0E-01	2.1E+01	1.8E+02	3.9E+01
DICHLOROPROPANE, 1,2-	5.0E+00	Drinking Water Toxicity	1.0E-01	5.0E+00	2.9E+03	1.7E+03
DICHLOROPROPENE, 1,3-	5.0E-01	Drinking Water Toxicity	5.0E+04	5.0E-01	1.2E+02	
DIELDRIN	2.2E-03	Drinking Water Toxicity	4.1E-01	2.2E-03	5.6E-02	0.00014
DIETHYLPHTHALATE	1.5E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	5.6E+03	1.5E+00	120000
DIMETHYLPHTHALATE	1.5E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	7.0E+04	1.5E+00	2900000
DIMETHYLPHENOL, 2,4-	1.0E+02	Drinking Water Toxicity	4.0E+02	1.0E+02	5.3E+02	2300
DINITROPHENOL, 2,4-	1.4E+01	Drinking Water Toxicity	5.0E+04	1.4E+01	7.5E+01	1.4E+04
DINITROTOLUENE, 2,4-	1.1E-01	Drinking Water Toxicity	5.0E+04	1.1E-01	1.2E+02	9.1E+00
1,4 DIOXANE	3.0E+00	Bioaccumulation/Human Consumption	5.0E+04	3.0E+00	3.4E+05	
DIOXIN (2,3,7,8-TCDD)	1.4E-08	Bioaccumulation/Human Consumption	7.0E-03	3.0E-05	5.0E-06	1.4E-08
ENDOSULFAN	5.6E-02	Aquatic Habitat Chronic Toxicity	7.5E-01	4.2E+01	5.6E-02	2.4E+02
ENDRIN	3.6E-02	Aquatic Habitat Chronic Toxicity	4.1E-01	2.0E+00	3.6E-02	8.1E-01
ETHANOL	5.0E+04	Ceiling Value	5.0E+04			
ETHYLBENZENE	3.0E+01	Ceiling Value	3.0E+01	7.0E+02	2.9E+02	2.9E+04
FLUORANTHENE	8.1E+00	Aquatic Habitat Chronic Toxicity	1.3E-02	2.8E+02	8.1E+00	3.7E+02
FLUORENE	3.9E+00	Aquatic Habitat Chronic Toxicity	9.5E-02	2.8E+02	3.9E+00	1.4E+04

TABLE F-2a. SURFACE WATER SCREENING LEVELS
Fresh Water Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Ceiling Value (Taste & Odors, etc.) Table I-3	Drinking Water (Toxicity) Table F-3	Fresh Water Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
HEPTACHLOR	2.1E-04	Bioaccumulation/Human Consumption	2.0E-01	1.0E-02	3.8E-03	2.1E-04
HEPTACHLOR EPOXIDE	1.1E-04	Bioaccumulation/Human Consumption	1.8E-02	1.0E-02	3.8E-03	1.1E-04
HEXACHLOROBENZENE	7.7E-04	Bioaccumulation/Human Consumption	5.5E-01	1.0E+00	3.7E+00	7.7E-04
HEXACHLOROBUTADIENE	2.1E-01	Drinking Water Toxicity	6.0E-00	2.1E-01	4.7E+00	5.0E+01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	6.3E-02	Bioaccumulation/Human Consumption	3.5E-03	2.0E-01	8.0E-02	6.3E-02
HEXACHLOROETHANE	7.0E-01	Drinking Water Toxicity	1.0E-01	7.0E-01	1.2E+01	8.9E+00
INDENO(1,2,3-cd)PYRENE	2.9E-02	Drinking Water Toxicity	2.7E-01	2.9E-02	2.9E-02	4.9E-02
LEAD	2.5E+00	Aquatic Habitat Chronic Toxicity	5.0E-04	1.5E+01	2.5E+00	
MERCURY	1.2E-02	Aquatic Habitat Chronic Toxicity	5.0E-04	2.0E+00	1.2E-02	5.1E-02
METHOXYCHLOR	1.9E-02	Aquatic Habitat Chronic Toxicity	2.0E-01	4.0E+01	1.9E-02	
METHYLENE CHLORIDE	5.0E+00	Drinking Water Toxicity	9.1E-03	5.0E+00	2.2E+03	1.6E+03
METHYL ETHYL KETONE	4.2E+03	Drinking Water Toxicity	8.4E-03	4.2E+03	1.4E+04	
METHYL ISOBUTYL KETONE	1.2E+02	Drinking Water Toxicity	1.3E-03	1.2E+02	1.7E+02	
METHYL MERCURY	3.0E-03	Aquatic Habitat Chronic Toxicity	5.0E-04	7.0E-02	3.0E-03	
METHYLNAPHTHALENE (total 1- & 2-)	2.1E+00	Aquatic Habitat Chronic Toxicity	1.0E+01	2.8E+02	2.1E+00	
METHYL TERT BUTYL ETHER	5.0E+00	Ceiling Value	5.0E+00	1.3E+01	6.6E+04	
MOLYBDENUM	3.5E+01	Drinking Water Toxicity	5.0E-04	3.5E+01	2.4E+02	
NAPHTHALENE	1.7E+01	Drinking Water Toxicity	2.1E-01	1.7E+01	2.4E+01	
NICKEL	5.2E+01	Aquatic Habitat Chronic Toxicity	5.0E-04	1.0E+02	5.2E+01	4.6E+03
PENTACHLOROPHENOL	1.0E+00	Drinking Water Toxicity	3.0E-01	1.0E+00	1.5E+01	8.2E+00
PERCHLORATE	6.0E+00	Drinking Water Toxicity	5.0E-04	6.0E+00	6.0E+02	
PHENANTHRENE	6.3E+00	Aquatic Habitat Chronic Toxicity	4.1E-02	2.8E+02	6.3E+00	4.6E+06
PHENOL	5.0E+00	Ceiling Value	5.0E-00	4.2E+03	1.3E+03	1.7E-04
POLYCHLORINATED BIPHENYLS (PCBs)	1.7E-04	Bioaccumulation/Human Consumption	1.6E-01	5.0E-01	1.4E-02	1.7E-04
PYRENE	2.0E+00	Aquatic Habitat Chronic Toxicity	6.8E-01	2.1E+02	2.0E+00	1.1E+04
SELENIUM	5.0E+00	Aquatic Habitat Chronic Toxicity	5.0E-04	5.0E+01	5.0E+00	
SILVER	3.4E-01	Aquatic Habitat Chronic Toxicity	1.0E-02	1.0E+02	3.4E-01	
STYRENE	1.0E+01	Ceiling Value	1.0E-01	1.0E+02	1.0E+02	
tert-BUTYL ALCOHOL	1.2E+01	Drinking Water Toxicity	5.0E-04	1.2E+01	1.8E+04	
TETRACHLOROETHANE, 1,1,1,2-	1.3E+00	Drinking Water Toxicity	5.0E-04	1.3E+00	9.3E+02	
TETRACHLOROETHANE, 1,1,2,2-	1.0E+00	Drinking Water Toxicity	5.0E-02	1.0E+00	4.2E+02	1.1E+01
TETRACHLOROETHYLENE	5.0E+00	Drinking Water Toxicity	1.7E-02	5.0E+00	1.2E+02	8.9E+00
THALLIUM	2.0E+00	Drinking Water Toxicity	5.0E-04	2.0E+00	2.0E+01	6.3E+00
TOLUENE	4.0E+01	Ceiling Value	4.0E+01	1.5E+02	1.3E+02	2.0E+05
TOXAPHENE	2.0E-04	Aquatic Habitat Chronic Toxicity	1.4E-02	3.0E+00	2.0E-04	7.5E-04
TPH (gasolines)	1.0E+02	Ceiling Value	1.0E+02	2.1E+02	5.0E+02	

TABLE F-2a. SURFACE WATER SCREENING LEVELS
Fresh Water Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Ceiling Value (Taste & Odors, etc.) Table I-3	Drinking Water (Toxicity) Table F-3	Fresh Water Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
TPH (middle distillates)	1.0E+02	Ceiling Value	1.0E+02	2.1E+02	6.4E+02	
TPH (residual fuels)	1.0E+02	Ceiling Value	1.0E+02	2.1E+02	6.4E+02	
TRICHLOROBENZENE, 1,2,4-	2.5E+01	Aquatic Habitat Chronic Toxicity	3.0E+03	7.0E+01	2.5E+01	
TRICHLOROETHANE, 1,1,1-	6.2E+01	Aquatic Habitat Chronic Toxicity	9.7E+02	2.0E+02	6.2E+01	
TRICHLOROETHANE, 1,1,2-	5.0E+00	Drinking Water Toxicity	5.0E+04	5.0E+00	4.7E+03	4.2E+01
TRICHLOROETHYLENE	5.0E+00	Drinking Water Toxicity	3.1E+02	5.0E+00	3.6E+02	8.1E+01
TRICHLOROPHENOL, 2,4,5-	6.3E+01	Aquatic Habitat Chronic Toxicity	2.0E+02	7.0E+02	6.3E+01	3.6E+03
TRICHLOROPHENOL, 2,4,6-	5.0E-01	Drinking Water Toxicity	1.0E+02	5.0E-01	4.9E+02	6.5E+00
VANADIUM	1.5E+01	Drinking Water Toxicity	5.0E-04	1.5E+01	1.9E+01	
VINYL CHLORIDE	5.0E-01	Drinking Water Toxicity	3.4E+03	5.0E-01	7.8E+02	5.3E+02
XYLENES	2.0E+01	Ceiling Value	2.0E+01	1.8E+03	1.0E+02	
ZINC	1.2E+02	Aquatic Habitat Chronic Toxicity	5.0E-03	5.0E+03	1.2E+02	

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Lowest of ceiling value, drinking water goal, aquatic habitat goal, and bioaccumulation goal.

TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

Ceiling Level: Odor threshold, 1/2 solubility or 50000 ug/L maximum, whichever is lower. Intended to limit nuisances and general resource degradation.

Review of aquatic ecotoxicity data for ethanol underway. Based on preliminary review of available data, chronic toxicity screening levels likely to be significantly greater than ceiling level of 50,000 ug/L (refer to USEPA 2003b, ECOTOX database).

Method detection limits and background concentrations replace final screening level as appropriate.

TABLE F-2b. SURFACE WATER SCREENING LEVELS
Marine Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Marine Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
ACENAPHTHENE	2.0E+01	Ceiling Level	2.0E+01	4.0E+01	2.7E+03
ACENAPHTHYLENE	3.0E+01	Aquatic Habitat Chronic Toxicity	2.0E+03	3.0E+01	
ACETONE	1.5E+03	Aquatic Habitat Chronic Toxicity	2.0E+04	1.5E+03	
ALDRIN	1.4E-04	Bioaccumulation/Human Consumption	8.5E+00	1.3E-01	1.4E-04
ANTHRACENE	7.3E-01	Aquatic Habitat Chronic Toxicity	2.2E+01	7.3E-01	1.1E-05
ANTIMONY	5.0E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	5.0E+02	4.3E-03
ARSENIC	1.4E-01	Bioaccumulation/Human Consumption	5.0E+04	3.6E+01	1.4E-01
BARIUM	1.0E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	1.0E+03	
BENZENE	7.1E+01	Bioaccumulation/Human Consumption	2.0E+03	3.5E+02	7.1E-01
BENZO(a)ANTHRACENE	2.7E-02	Aquatic Habitat Chronic Toxicity	5.0E+00	2.7E-02	4.9E-02
BENZO(b)FLUORANTHENE	2.9E-02	Aquatic Habitat Chronic Toxicity	7.0E+00	2.9E-02	4.9E-02
BENZO(k)FLUORANTHENE	4.9E-02	Bioaccumulation/Human Consumption	4.0E-01	3.7E+00	4.9E-02
BENZO(g,h,i)PERYLENE	1.0E-01	Aquatic Habitat Chronic Toxicity	1.3E-01	1.0E-01	
BENZO(a)PYRENE	1.4E-02	Aquatic Habitat Chronic Toxicity	1.9E+00	1.4E-02	4.9E-02
BERYLLIUM	2.7E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	2.7E+00	
BIPHENYL, 1,1-	5.0E-01	Ceiling Level	5.0E-01	1.4E+01	
BIS(2-CHLOROETHYL)ETHER	1.4E+00	Bioaccumulation/Human Consumption	3.6E+02	6.1E+01	1.4E+00
BIS(2-CHLOROISOPROPYL)ETHER	6.1E+01	Aquatic Habitat Chronic Toxicity	3.2E+02	6.1E+01	1.7E+05
BIS(2-ETHYLHEXYL)PHTHALATE	5.9E+00	Bioaccumulation/Human Consumption	6.5E+02	3.2E+01	5.9E+00
BORON	1.6E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.6E+00	
BROMODICHLOROMETHANE	3.2E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	3.2E+03	
BROMOFORM	3.6E+02	Bioaccumulation/Human Consumption	5.1E+02	3.2E+03	3.6E+02
BROMOMETHANE	3.2E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	3.2E+03	4.0E+03
CADMIUM	9.3E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	9.3E+00	
CARBON TETRACHLORIDE	4.4E+00	Bioaccumulation/Human Consumption	5.2E+02	3.2E+03	4.4E+00
CHLORDANE	5.9E-04	Bioaccumulation/Human Consumption	2.5E+00	4.0E-03	5.9E-04
CHLOROANILINE, p-	5.0E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	5.0E+00	
CHLOROBENZENE	5.0E+01	Ceiling Level	5.0E+01	6.5E+01	2.1E+04
CHLOROETHANE	1.2E+01	Aquatic Habitat Chronic Toxicity	1.6E+01	1.2E+01	
CHLOROFORM	4.7E+02	Bioaccumulation/Human Consumption	2.4E+03	3.2E+03	4.7E+02
CHLOROMETHANE	3.2E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	3.2E+03	
CHLOROPHENOL, 2-	1.8E-01	Ceiling Level	1.8E-01	4.4E+02	4.0E+02
CHROMIUM (Total)	1.8E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.8E+02	
CHROMIUM III	1.8E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.8E+02	
CHROMIUM VI	5.0E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	5.0E+01	
CHRYSENE	4.9E-02	Bioaccumulation/Human Consumption	8.0E-01	3.5E-01	4.9E-02

TABLE F-2b. SURFACE WATER SCREENING LEVELS
Marine Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Marine Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
COBALT	3.0E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	3.0E+00	
COPPER	3.1E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	3.1E+00	
CYANIDE (Free)	1.0E+00	Aquatic Habitat Chronic Toxicity	1.7E+02	1.0E+00	2.2E-05
DIBENZO(a,h)ANTHTRACENE	4.9E-02	Bioaccumulation/Human Consumption	2.5E-01	7.5E+00	4.9E-02
DIBROMOCHLOROMETHANE	4.6E+01	Bioaccumulation/Human Consumption	5.0E+04	3.2E+03	4.6E+01
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-01	Aquatic Habitat Chronic Toxicity	1.0E+01	2.0E-01	
DIBROMOETHANE, 1,2-	1.4E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	1.4E+03	
DICHLOROBENZENE, 1,2-	1.0E+01	Ceiling Level	1.0E+01	6.5E+01	1.7E-04
DICHLOROBENZENE, 1,3-	6.5E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	6.5E+01	2.6E-03
DICHLOROBENZENE, 1,4-	1.1E+01	Ceiling Level	1.1E+01	6.5E+01	2.6E-03
DICHLOROBENZIDINE, 3,3-	7.7E-02	Bioaccumulation/Human Consumption	1.6E+03	2.5E+02	7.7E-02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.4E-04	Bioaccumulation/Human Consumption	8.0E+01	1.0E-03	8.4E-04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	5.9E-04	Bioaccumulation/Human Consumption	2.0E+01	1.0E-03	5.9E-04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	5.9E-04	Bioaccumulation/Human Consumption	1.5E+00	1.0E-03	5.9E-04
DICHLOROETHANE, 1,1-	4.7E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	4.7E+01	
DICHLOROETHANE, 1,2-	9.9E-01	Bioaccumulation/Human Consumption	2.0E+04	1.0E+04	9.9E-01
DICHLOROETHYLENE, 1,1-	3.2E+00	Bioaccumulation/Human Consumption	1.5E+03	2.5E+01	3.2E+00
DICHLOROETHYLENE, Cis 1,2-	5.9E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	5.9E+02	
DICHLOROETHYLENE, Trans 1,2-	2.6E+02	Ceiling Level	2.6E+02	5.9E+02	7.9E-02
DICHLOROPHENOL, 2,4-	3.0E-01	Ceiling Level	3.0E-01	1.8E+02	7.9E-02
DICHLOROPROPANE, 1,2-	1.0E+01	Ceiling Level	1.0E+01	1.5E+03	3.9E-01
DICHLOROPROPENE, 1,3-	1.2E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.2E+02	1.7E-03
DIELDRIN	1.9E-03	Aquatic Habitat Chronic Toxicity	4.1E+01	1.9E-03	0.00014
DIETHYLPHTHALATE	1.7E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.7E+00	120000
DIMETHYLPHTHALATE	1.7E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.7E+00	2900000
DIMETHYLPHENOL, 2,4-	1.1E+02	Aquatic Habitat Chronic Toxicity	4.0E+02	1.1E+02	2300
DINITROPHENOL, 2,4-	7.5E-01	Aquatic Habitat Chronic Toxicity	5.0E+04	7.5E+01	1.4E+04
DINITROTOLUENE, 2,4-	9.1E+00	Bioaccumulation/Human Consumption	5.0E+04	1.9E+02	9.1E+00
1,4 DIOXANE	5.0E-04	Ceiling Level	5.0E-04	5.0E+05	
DIOXIN (2,3,7,8-TCDD)	1.4E-08	Bioaccumulation/Human Consumption	7.0E+03	5.0E-06	1.4E-08
ENDOSULFAN	8.7E-03	Aquatic Habitat Chronic Toxicity	7.5E+01	8.7E-03	2.4E+02
ENDRIN	2.3E-03	Aquatic Habitat Chronic Toxicity	4.1E+01	2.3E-03	8.1E-01
ETHANOL	5.0E+04	Ceiling Level	5.0E+04		
ETHYLBENZENE	3.0E+01	Ceiling Level	3.0E+01	2.9E+02	2.9E-04
FLUORANTHENE	8.0E+00	Aquatic Habitat Chronic Toxicity	1.3E+02	8.0E+00	3.7E+02
FLUORENE	3.9E+00	Aquatic Habitat Chronic Toxicity	9.5E+02	3.9E+00	1.4E-04

TABLE F-2b. SURFACE WATER SCREENING LEVELS
Marine Habitats
(ug/l)

CHEMICAL PARAMETER	¹Final Surface Water Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Marine Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
HEPTACHLOR	2.1E-04	Bioaccumulation/Human Consumption	2.0E+01	0.0036	2.1E-04
HEPTACHLOR EPOXIDE	1.1E-04	Bioaccumulation/Human Consumption	1.8E+02	0.0036	1.1E-04
HEXACHLOROBENZENE	7.7E-04	Bioaccumulation/Human Consumption	5.5E+01	6.5E+01	7.7E-04
HEXACHLOROBUTADIENE	4.7E+00	Aquatic Habitat Chronic Toxicity	6.0E+00	4.7E+00	5.0E+01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	6.3E-02	Bioaccumulation/Human Consumption	3.5E+03	8.0E-02	6.3E-02
HEXACHLOROETHANE	8.9E+00	Bioaccumulation/Human Consumption	1.0E+01	1.2E+01	8.9E+00
INDENO(1,2,3-cd)PYRENE	2.9E-02	Aquatic Habitat Chronic Toxicity	2.7E-01	2.9E-02	4.9E-02
LEAD	8.1E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	8.1E+00	
MERCURY	2.5E-02	Aquatic Habitat Chronic Toxicity	5.0E+04	2.5E-02	5.1E-02
METHOXYCHLOR	1.9E-02	Aquatic Habitat Chronic Toxicity	2.0E+01	1.9E-02	
METHYLENE CHLORIDE	1.6E+03	Bioaccumulation/Human Consumption	9.1E+03	3.2E+03	1.6E+03
METHYL ETHYL KETONE	8.4E+03	Ceiling Level	8.4E+03	1.4E+04	
METHYL ISOBUTYL KETONE	1.7E+02	Aquatic Habitat Chronic Toxicity	1.3E+03	1.7E+02	
METHYL MERCURY	3.0E-03	Aquatic Habitat Chronic Toxicity	5.0E+04	3.0E-03	
METHYLNAPHTHALENE (total 1- & 2-)	2.1E+00	Aquatic Habitat Chronic Toxicity	1.0E+01	2.1E+00	
METHYL TERT BUTYL ETHER	1.8E+02	Ceiling Level	1.8E+02	8.0E+03	
MOLYBDENUM	2.4E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	2.4E+02	
NAPHTHALENE	2.1E+01	Ceiling Level	2.1E+01	2.4E+01	
NICKEL	8.2E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	8.2E+00	4.6E+03
PENTACHLOROPHENOL	7.9E+00	Aquatic Habitat Chronic Toxicity	5.9E+02	7.9E+00	8.2E+00
PERCHLORATE	6.0E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	6.0E+02	
PHENANTHRENE	4.6E+00	Aquatic Habitat Chronic Toxicity	4.1E+02	4.6E+00	
PHENOL	1.3E+03	Aquatic Habitat Chronic Toxicity	7.9E+03	1.3E+03	4.6E+06
POLYCHLORINATED BIPHENYLS (PCBs)	1.7E-04	Bioaccumulation/Human Consumption	1.6E+01	3.0E-02	1.7E-04
PYRENE	2.0E+00	Aquatic Habitat Chronic Toxicity	6.8E+01	2.0E+00	1.1E+04
SELENIUM	7.1E-01	Aquatic Habitat Chronic Toxicity	5.0E+04	7.1E+01	
SILVER	1.9E-01	Aquatic Habitat Chronic Toxicity	5.0E+04	1.9E-01	
STYRENE	1.1E+01	Ceiling Level	1.1E+01	1.0E+02	
tert-BUTYL ALCOHOL	1.8E+04	Aquatic Habitat Chronic Toxicity	5.0E+04	1.8E+04	
TETRACHLOROETHANE, 1,1,1,2-	9.3E-02	Aquatic Habitat Chronic Toxicity	5.0E+04	9.3E-02	
TETRACHLOROETHANE, 1,1,2,2-	1.1E-01	Bioaccumulation/Human Consumption	5.0E+02	4.2E+02	1.1E+01
TETRACHLOROETHYLENE	8.9E+00	Bioaccumulation/Human Consumption	3.0E+02	2.3E+02	8.9E+00
THALLIUM	6.3E+00	Bioaccumulation/Human Consumption	5.0E+04	2.0E+01	6.3E+00
TOLUENE	4.0E+01	Ceiling Level	4.0E+01	2.5E+03	2.0E+05
TOXAPHENE	2.0E-04	Aquatic Habitat Chronic Toxicity	1.4E+02	2.0E-04	7.5E-04
TPH (gasolines)	3.7E+03	Aquatic Habitat Chronic Toxicity	5.0E+03	3.7E+03	

TABLE F-2b. SURFACE WATER SCREENING LEVELS
Marine Habitats
(ug/l)

CHEMICAL PARAMETER	¹Final Surface Water Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Marine Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
TPH (middle distillates)	6.4E+02	Aquatic Habitat Chronic Toxicity	2.5E+03	6.4E+02	
TPH (residual fuels)	6.4E+02	Aquatic Habitat Chronic Toxicity	2.5E+03	6.4E+02	
TRICHLOROBENZENE, 1,2,4-	6.5E+01	Aquatic Habitat Chronic Toxicity	3.0E+03	6.5E+01	
TRICHLOROETHANE, 1,1,1-	6.2E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	6.2E+01	
TRICHLOROETHANE, 1,1,2-	4.2E-01	Bioaccumulation/Human Consumption	5.0E+04	4.7E+03	4.2E-01
TRICHLOROETHYLENE	8.1E-01	Bioaccumulation/Human Consumption	1.0E+04	3.6E+02	8.1E-01
TRICHLOROPHENOL, 2,4,5-	1.1E+01	Aquatic Habitat Chronic Toxicity	2.0E+02	1.1E+01	3.6E-03
TRICHLOROPHENOL, 2,4,6-	6.5E+00	Bioaccumulation/Human Consumption	1.0E+02	4.9E+02	6.5E+00
VANADIUM	1.9E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	1.9E+01	
VINYL CHLORIDE	5.3E+02	Bioaccumulation/Human Consumption	3.4E+03	7.8E+02	5.3E+02
XYLENES	1.0E+02	Aquatic Habitat Chronic Toxicity	5.3E+02	1.0E+02	
ZINC	8.1E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	8.1E+01	

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Lowest of Ceiling Value, aquatic habitat goal, and bioaccumulation goal.

TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Ceiling Level: Odor threshold, 1/2 solubility or 50000 ug/L maximum, whichever is lower. Intended to limit nuisances and general resource degradation.
Review of aquatic ecotoxicty data for ethanol underway. Based on preliminary review of available data, chronic toxicity screening levels likely to be significantly greater than ceiling level of 50,000 ug/L (refer to USEPA 2003b, ECOTOX database).
Method detection limits and background concentrations replace final screening level as appropriate.

TABLE F-2c. SURFACE WATER SCREENING LEVELS
*Estuary Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Estuary Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
ACENAPHTHENE	2.0E+01	Ceiling Level	2.0E+01	2.3E+01	2.7E+03
ACENAPHTHYLENE	3.0E+01	Aquatic Habitat Chronic Toxicity	2.0E+03	3.0E+01	
ACETONE	1.5E+03	Aquatic Habitat Chronic Toxicity	2.0E+04	1.5E+03	
ALDRIN	1.4E-04	Bioaccumulation/Human Consumption	8.5E+00	1.3E-01	1.4E-04
ANTHRACENE	7.3E-01	Aquatic Habitat Chronic Toxicity	2.2E+01	7.3E-01	1.1E+05
ANTIMONY	3.0E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	3.0E+01	4.3E+03
ARSENIC	1.4E-01	Bioaccumulation/Human Consumption	5.0E+04	3.6E+01	1.4E-01
BARIUM	1.0E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	1.0E+03	
BENZENE	4.6E+01	Aquatic Habitat Chronic Toxicity	2.0E+03	4.6E+01	7.1E+01
BENZO(a)ANTHRACENE	2.7E-02	Aquatic Habitat Chronic Toxicity	5.0E+00	2.7E-02	4.9E-02
BENZO(b)FLUORANTHENE	2.9E-02	Aquatic Habitat Chronic Toxicity	7.0E+00	2.9E-02	4.9E-02
BENZO(k)FLUORANTHENE	4.9E-02	Bioaccumulation/Human Consumption	4.0E-01	3.7E+00	4.9E-02
BENZO(g,h,i)PERYLENE	1.0E-01	Aquatic Habitat Chronic Toxicity	1.3E-01	1.0E-01	
BENZO(a)PYRENE	1.4E-02	Aquatic Habitat Chronic Toxicity	1.9E+00	1.4E-02	4.9E-02
BERYLLIUM	2.7E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	2.7E+00	
BIPHENYL, 1,1-	5.0E-01	Ceiling Level	5.0E-01	1.4E+01	
BIS(2-CHLOROETHYL)ETHER	1.4E+00	Bioaccumulation/Human Consumption	3.6E+02	6.1E+01	1.4E+00
BIS(2-CHLOROISOPROPYL)ETHER	6.1E+01	Aquatic Habitat Chronic Toxicity	3.2E+02	6.1E+01	1.7E+05
BIS(2-ETHYLHEXYL)PHTHALATE	5.9E+00	Bioaccumulation/Human Consumption	6.5E+02	3.2E+01	5.9E+00
BORON	1.6E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.6E+00	
BROMODICHLOROMETHANE	3.2E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	3.2E+03	
BROMOFORM	3.6E+02	Bioaccumulation/Human Consumption	5.1E+02	3.2E+03	3.6E+02
BROMOMETHANE	1.6E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.6E+02	4.0E+03
CADMIUM	1.1E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.1E+00	
CARBON TETRACHLORIDE	4.4E+00	Bioaccumulation/Human Consumption	5.2E+02	9.8E+00	4.4E+00
CHLORDANE	5.9E-04	Bioaccumulation/Human Consumption	2.5E+00	4.0E-03	5.9E-04
CHLOROANILINE, p-	5.0E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	5.0E+00	
CHLOROBENZENE	2.5E+01	Aquatic Habitat Chronic Toxicity	5.0E+01	2.5E+01	2.1E+04
CHLOROETHANE	1.2E+01	Aquatic Habitat Chronic Toxicity	1.6E+01	1.2E+01	
CHLOROFORM	4.7E+02	Bioaccumulation/Human Consumption	2.4E+03	6.2E+02	4.7E+02
CHLOROMETHANE	3.2E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	3.2E+03	
CHLOROPHENOL, 2-	1.8E-01	Ceiling Level	1.8E-01	4.4E+02	4.0E+02
CHROMIUM (Total)	1.8E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.8E+02	
CHROMIUM III	1.8E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.8E+02	
CHROMIUM VI	1.1E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	1.1E+01	
CHRYSENE	4.9E-02	Bioaccumulation/Human Consumption	8.0E-01	3.5E-01	4.9E-02
COBALT	3.0E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	3.0E+00	

TABLE F-2c. SURFACE WATER SCREENING LEVELS
*Estuary Habitats
(ug/l)

CHEMICAL PARAMETER	Final Surface Water Screening Level[1]	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Estuary Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
COPPER	3.1E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	3.1E+00	
CYANIDE (Free)	1.0E+00	Aquatic Habitat Chronic Toxicity	1.7E+02	1.0E+00	2.2E-05
DIBENZO(a,h)ANTHRACENE	4.9E-02	Bioaccumulation/Human Consumption	2.5E-01	7.5E+00	4.9E-02
DIBROMOCHLOROMETHANE	4.6E+01	Bioaccumulation/Human Consumption	5.0E+04	3.2E+03	4.6E+01
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-01	Aquatic Habitat Chronic Toxicity	1.0E+01	2.0E-01	
DIBROMOETHANE, 1,2-	1.4E+03	Aquatic Habitat Chronic Toxicity	5.0E+04	1.4E+03	
DICHLOROBENZENE, 1,2-	1.0E+01	Ceiling Level	1.0E+01	1.4E+01	1.7E+04
DICHLOROBENZENE, 1,3-	6.5E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	6.5E+01	2.6E+03
DICHLOROBENZENE, 1,4-	1.1E+01	Ceiling Level	1.1E+01	1.5E+01	2.6E+03
DICHLOROBENZIDINE, 3,3-	7.7E-02	Bioaccumulation/Human Consumption	1.6E+03	2.5E+02	7.7E-02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.4E-04	Bioaccumulation/Human Consumption	8.0E+01	1.0E-03	8.4E-04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	5.9E-04	Bioaccumulation/Human Consumption	2.0E+01	1.0E-03	5.9E-04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	5.9E-04	Bioaccumulation/Human Consumption	1.5E+00	1.0E-03	5.9E-04
DICHLOROETHANE, 1,1-	4.7E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	4.7E+01	
DICHLOROETHANE, 1,2-	9.9E+01	Bioaccumulation/Human Consumption	2.0E+04	1.0E+04	9.9E+01
DICHLOROETHYLENE, 1,1-	3.2E+00	Bioaccumulation/Human Consumption	1.5E+03	2.5E+01	3.2E+00
DICHLOROETHYLENE, Cis 1,2-	5.9E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	5.9E+02	
DICHLOROETHYLENE, Trans 1,2-	2.6E+02	Ceiling Level	2.6E+02	5.9E+02	140000
DICHLOROPHENOL, 2,4-	3.0E-01	Ceiling Level	3.0E-01	1.8E+02	7.9E+02
DICHLOROPROPANE, 1,2-	1.0E+01	Ceiling Level	1.0E+01	1.5E+03	3.9E+01
DICHLOROPROPENE, 1,3-	1.2E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.2E+02	1.7E+03
DIELDRIN	1.9E-03	Aquatic Habitat Chronic Toxicity	4.1E+01	1.9E-03	0.00014
DIETHYLPHTHALATE	1.5E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.5E+00	120000
DIMETHYLPHTHALATE	1.5E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	1.5E+00	2900000
DIMETHYLPHENOL, 2,4-	1.1E+02	Aquatic Habitat Chronic Toxicity	4.0E+02	1.1E+02	2300
DINITROPHENOL, 2,4-	7.5E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	7.5E+01	1.4E+04
DINITROTOLUENE, 2,4-	9.1E+00	Bioaccumulation/Human Consumption	5.0E+04	1.2E+02	9.1E+00
1,4 DIOXANE	5.0E+04	Ceiling Level	5.0E+04	3.4E+05	
DIOXIN (2,3,7,8-TCDD)	1.4E-08	Bioaccumulation/Human Consumption	7.0E+03	5.0E-06	1.4E-08
ENDOSULFAN	8.7E-03	Aquatic Habitat Chronic Toxicity	7.5E+01	8.7E-03	2.4E+02
ENDRIN	2.3E-03	Aquatic Habitat Chronic Toxicity	4.1E+01	2.3E-03	8.1E-01
ETHANOL	5.0E+04	Ceiling Level	5.0E+04		
ETHYLBENZENE	3.0E+01	Ceiling Level	3.0E+01	2.9E+02	2.9E+04
FLUORANTHENE	8.0E+00	Aquatic Habitat Chronic Toxicity	1.3E+02	8.0E+00	3.7E+02
FLUORENE	3.9E+00	Aquatic Habitat Chronic Toxicity	9.5E+02	3.9E+00	1.4E+04
HEPTACHLOR	2.1E-04	Bioaccumulation/Human Consumption	2.0E+01	3.8E-03	2.1E-04
HEPTACHLOR EPOXIDE	1.1E-04	Bioaccumulation/Human Consumption	1.8E+02	3.8E-03	1.1E-04

TABLE F-2c. SURFACE WATER SCREENING LEVELS
*Estuary Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Estuary Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
HEXACHLOROBENZENE	7.7E-04	Bioaccumulation/Human Consumption	5.5E+01	3.7E+00	7.7E-04
HEXACHLOROBUTADIENE	4.7E+00	Aquatic Habitat Chronic Toxicity	6.0E+00	4.7E+00	5.0E+01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	6.3E-02	Bioaccumulation/Human Consumption	3.5E+03	8.0E-02	6.3E-02
HEXACHLOROETHANE	8.9E+00	Bioaccumulation/Human Consumption	1.0E+01	1.2E+01	8.9E+00
INDENO(1,2,3-cd)PYRENE	2.9E-02	Aquatic Habitat Chronic Toxicity	2.7E-01	2.9E-02	4.9E-02
LEAD	2.5E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	2.5E+00	
MERCURY	1.2E-02	Aquatic Habitat Chronic Toxicity	5.0E+04	1.2E-02	5.1E-02
METHOXYCHLOR	1.9E-02	Aquatic Habitat Chronic Toxicity	2.0E+01	1.9E-02	
METHYLENE CHLORIDE	1.6E+03	Bioaccumulation/Human Consumption	9.1E+03	2.2E+03	1.6E+03
METHYL ETHYL KETONE	8.4E+03	Ceiling Level	8.4E+03	1.4E+04	
METHYL ISOBUTYL KETONE	1.7E+02	Aquatic Habitat Chronic Toxicity	1.3E+03	1.7E+02	
METHYL MERCURY	3.0E-03	Aquatic Habitat Chronic Toxicity	5.0E+04	3.0E-03	
METHYLNAPHTHALENE (total 1- & 2-)	2.1E+00	Aquatic Habitat Chronic Toxicity	1.0E+01	2.1E+00	
METHYL TERT BUTYL ETHER	1.8E+02	Ceiling Level	1.8E+02	8.0E+03	
MOLYBDENUM	2.4E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	2.4E+02	
NAPHTHALENE	2.1E+01	Ceiling Level	2.1E+01	2.4E+01	
NICKEL	8.2E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	8.2E+00	4.6E+03
PENTACHLOROPHENOL	7.9E+00	Aquatic Habitat Chronic Toxicity	5.9E+02	7.9E+00	8.2E+00
PERCHLORATE	6.0E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	6.0E+02	
PHENANTHRENE	4.6E+00	Aquatic Habitat Chronic Toxicity	4.1E+02	4.6E+00	
PHENOL	1.3E+03	Aquatic Habitat Chronic Toxicity	7.9E+03	1.3E+03	4.6E+06
POLYCHLORINATED BIPHENYLS (PCBs)	1.7E-04	Bioaccumulation/Human Consumption	1.6E+01	1.4E-02	1.7E-04
PYRENE	2.0E+00	Aquatic Habitat Chronic Toxicity	6.8E+01	2.0E+00	1.1E+04
SELENIUM	5.0E+00	Aquatic Habitat Chronic Toxicity	5.0E+04	5.0E+00	
SILVER	1.9E-01	Aquatic Habitat Chronic Toxicity	5.0E+04	1.9E-01	
STYRENE	1.1E+01	Ceiling Level	1.1E+01	1.0E+02	
tert-BUTYL ALCOHOL	1.8E+04	Aquatic Habitat Chronic Toxicity	5.0E+04	1.8E+04	
TETRACHLOROETHANE, 1,1,1,2-	9.3E+02	Aquatic Habitat Chronic Toxicity	5.0E+04	9.3E+02	
TETRACHLOROETHANE, 1,1,2,2-	1.1E+01	Bioaccumulation/Human Consumption	5.0E+02	4.2E+02	1.1E+01
TETRACHLOROETHYLENE	8.9E+00	Bioaccumulation/Human Consumption	3.0E+02	1.2E+02	8.9E+00
THALLIUM	6.3E+00	Bioaccumulation/Human Consumption	5.0E+04	2.0E+01	6.3E+00
TOLUENE	4.0E+01	Ceiling Level	4.0E+01	1.3E+02	2.0E+05
TOXAPHENE	2.0E-04	Aquatic Habitat Chronic Toxicity	1.4E+02	2.0E-04	7.5E-04
TPH (gasolines)	5.0E+02	Aquatic Habitat Chronic Toxicity	5.0E+03	5.0E+02	
TPH (middle distillates)	6.4E+02	Aquatic Habitat Chronic Toxicity	2.5E+03	6.4E+02	
TPH (residual fuels)	6.4E+02	Aquatic Habitat Chronic Toxicity	2.5E+03	6.4E+02	
TRICHLOROBENZENE, 1,2,4-	2.5E+01	Aquatic Habitat Chronic Toxicity	3.0E+03	2.5E+01	

TABLE F-2c. SURFACE WATER SCREENING LEVELS
*Estuary Habitats
(ug/l)

CHEMICAL PARAMETER	[1]Final Surface Water Screening Level	Basis	Gross Contamination Ceiling Value (Odors, etc.) Table I-4	Estuary Aquatic Habitat Goal (Chronic Toxicity) Table F-4a	Bioaccumulation and Human Consumption Table F-4d
TRICHLOROETHANE, 1,1,1-	6.2E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	6.2E+01	
TRICHLOROETHANE, 1,1,2-	4.2E+01	Bioaccumulation/Human Consumption	5.0E+04	4.7E+03	4.2E+01
TRICHLOROETHYLENE	8.1E+01	Bioaccumulation/Human Consumption	1.0E+04	3.6E+02	8.1E+01
TRICHLOROPHENOL, 2,4,5-	1.1E+01	Aquatic Habitat Chronic Toxicity	2.0E+02	1.1E+01	3.6E+03
TRICHLOROPHENOL, 2,4,6-	6.5E+00	Bioaccumulation/Human Consumption	1.0E+02	4.9E+02	6.5E+00
VANADIUM	1.9E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	1.9E+01	
VINYL CHLORIDE	5.3E+02	Bioaccumulation/Human Consumption	3.4E+03	7.8E+02	5.3E+02
XYLENES	1.0E+02	Aquatic Habitat Chronic Toxicity	5.3E+02	1.0E+02	
ZINC	8.1E+01	Aquatic Habitat Chronic Toxicity	5.0E+04	8.1E+01	

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

*Estuary Habitats: Mixed freshwater/marine water habitats.

1. Lowest of Ceiling Value, aquatic habitat goal, and bioaccumulation goal.

TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Ceiling Level: Odor threshold, 1/2 solubility or 50000 ug/L maximum, whichever is lower. Intended to limit
nuisances and general resource degradation.
Review of aquatic ecotoxicty data for ethanol underway. Based on preliminary review of available data, chronic toxicity screening levels likely to be
significantly greater than ceiling level of 50,000 ug/L (refer to USEPA 2003b, ECOTOX database).
Method detection limits and background concentrations replace final screening level as appropriate.

TABLE F-3. SUMMARY OF DRINKING WATER SCREENING LEVELS FOR HUMAN TOXICITY

(ug/L)

CHEMICAL PARAMETER	Final Screening Level	Basis	Cal DHS Primary MCL	Other CalEPA Criteria	Reference	*Risk-Based Goals (Drinking Water Toxicity)	Basis
ACENAPHTHENE	4.2E+02	Noncarcinogenic Effects				4.2E+02	Noncarcinogenic Effects
ACENAPHTHYLENE	2.8E+02	Noncarcinogenic Effects				2.8E+02	Noncarcinogenic Effects
ACETONE	6.3E+03	Noncarcinogenic Effects				6.3E+03	Noncarcinogenic Effects
ALDRIN	2.0E-03	Cal DHS AL		2.0E-03	Cal DHS AL	2.1E-03	Carcinogenic Effects
ANTHRACENE	2.1E+03	Noncarcinogenic Effects				2.1E+03	Noncarcinogenic Effects
ANTIMONY	6.0E+00	Cal DHS Primary MCL	6.0E+00	2.0E+01	Cal OEHHA PHG	2.8E+00	Noncarcinogenic Effects
ARSENIC	5.0E+01	Cal DHS Primary MCL	5.0E+01			3.7E-03	Carcinogenic Effects
BARIUM	1.0E+03	Cal DHS Primary MCL	1.0E+03	2.0E+03	Cal OEHHA PHG	4.9E+02	Noncarcinogenic Effects
BENZENE	1.0E+00	Cal DHS Primary MCL	1.0E+00	1.5E-01	Cal OEHHA PHG	3.5E-01	Carcinogenic Effects
BENZO(a)ANTHRACENE	2.9E-02	Carcinogenic Effects				2.9E-02	Carcinogenic Effects
BENZO(b)FLUORANTHENE	2.9E-02	Carcinogenic Effects				2.9E-02	Carcinogenic Effects
BENZO(k)FLUORANTHENE	2.9E-02	Carcinogenic Effects				2.9E-02	Carcinogenic Effects
BENZO(g,h,i)PERYLENE	2.8E+02	Noncarcinogenic Effects				2.8E+02	Noncarcinogenic Effects
BENZO(a)PYRENE	2.0E-01	Cal DHS Primary MCL	2.0E-01			2.9E-03	Carcinogenic Effects
BERYLLIUM	4.0E+00	Cal DHS Primary MCL	4.0E+00			1.4E+01	Noncarcinogenic Effects
BIPHENYL, 1,1-	3.5E+02	Noncarcinogenic Effects				3.5E+02	Noncarcinogenic Effects
BIS(2-CHLOROETHYL)ETHER	1.4E-02	Carcinogenic Effects				1.4E-02	Carcinogenic Effects
BIS(2-CHLOROISOPROPYL)ETHER	5.0E-01	Carcinogenic Effects				5.0E-01	Carcinogenic Effects
BIS(2-ETHYLHEXYL)PHTHALATE	4.0E+00	Cal DHS Primary MCL	4.0E+00			1.2E+01	Carcinogenic Effects
BORON	1.0E+03	Cal DHS AL		1.0E+03	Cal DHS AL	1.4E+03	Noncarcinogenic Effects
BROMODICHLOROMETHANE	1.0E+02	Cal DHS Primary MCL	1.0E+02			2.7E-01	Carcinogenic Effects
BROMOFORM	1.0E+02	Cal DHS Primary MCL	1.0E+02			4.4E+00	Carcinogenic Effects
BROMOMETHANE	9.8E+00	Noncarcinogenic Effects				9.8E+00	Noncarcinogenic Effects
CADMIUM	5.0E+00	Cal DHS Primary MCL	5.0E+00	7.0E-02	Cal OEHHA PHG	9.2E-02	Carcinogenic Effects
CARBON TETRACHLORIDE	5.0E-01	Cal DHS Primary MCL	5.0E-01	1.0E-01	Cal OEHHA PHG	2.3E-01	Carcinogenic Effects
CHLORDANE	1.0E-01	Cal DHS Primary MCL	1.0E-01	3.0E-02	Cal OEHHA PHG	2.7E-02	Carcinogenic Effects
CHLOROANILINE, p-	2.8E+01	Noncarcinogenic Effects				2.8E+01	Noncarcinogenic Effects
CHLOROBENZENE	7.0E+01	Cal DHS Primary MCL	7.0E+01	2.0E+02	Cal OEHHA PHG	1.4E+02	Noncarcinogenic Effects
CHLOROETHANE	1.2E+01	Carcinogenic Effects				1.2E+01	Carcinogenic Effects
CHLOROFORM	7.0E+01	Cal DHS Primary MCL	7.0E+01			1.1E+00	Carcinogenic Effects
CHLOROMETHANE	1.3E+00	Carcinogenic Effects				1.3E+00	Carcinogenic Effects
CHLOROPHENOL, 2-	3.5E+01	Noncarcinogenic Effects				3.5E+01	Noncarcinogenic Effects
CHROMIUM (Total)	5.0E+01	Cal DHS Primary MCL	5.0E+01			-	
CHROMIUM III	2.0E+05	Cal OEHHA PHG		2.0E+05	Cal OEHHA PHG	1.1E+04	Noncarcinogenic Effects
CHROMIUM VI	2.1E+01	Noncarcinogenic Effects				2.1E+01	Noncarcinogenic Effects
CHRYSENE	2.9E-01	Carcinogenic Effects				2.9E-01	Carcinogenic Effects
COBALT	1.4E+02	Noncarcinogenic Effects				1.4E+02	Noncarcinogenic Effects

TABLE F-3. SUMMARY OF DRINKING WATER SCREENING LEVELS FOR HUMAN TOXICITY
(ug/L)

CHEMICAL PARAMETER	Final Screening Level	Basis	Cal DHS Primary MCL	Other CalEPA Criteria	Reference	*Risk-Based Goals (Drinking Water Toxicity)	Basis
COPPER	1.3E+03	Cal DHS Primary MCL	1.3E+03	1.7E+02	Cal OEHHA PHG	2.8E+02	Noncarcinogenic Effects
CYANIDE (Free)	2.0E+02	Cal DHS Primary MCL	2.0E+02	1.5E+02	Cal OEHHA PHG	1.4E+02	Noncarcinogenic Effects
DIBENZO(a,h)ANTHRACENE	8.5E-03	Carcinogenic Effects				8.5E-03	Carcinogenic Effects
DIBROMOCHLOROMETHANE	1.0E+02	Cal DHS Primary MCL	1.0E+02			3.7E-01	Carcinogenic Effects
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-01	Cal DHS Primary MCL	2.0E-01	1.7E-03	Cal OEHHA PHG	5.0E-03	Carcinogenic Effects
DIBROMOETHANE, 1,2-	5.0E-02	Cal DHS Primary MCL	5.0E-02			9.7E-03	Carcinogenic Effects
DICHLOROBENZENE, 1,2-	6.0E+02	Cal DHS Primary MCL	6.0E+02	6.0E+02	Cal OEHHA PHG	6.3E+02	Noncarcinogenic Effects
DICHLOROBENZENE, 1,3-	2.1E+02	Noncarcinogenic Effects				2.1E+02	Noncarcinogenic Effects
DICHLOROBENZENE, 1,4-	5.0E+00	Cal DHS Primary MCL	5.0E+00	6.0E+00	Cal OEHHA PHG	6.5E+00	Carcinogenic Effects
DICHLOROBENZIDINE, 3,3-	2.9E-02	Carcinogenic Effects				2.9E-02	Carcinogenic Effects
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.5E-01	Carcinogenic Effects				1.5E-01	Carcinogenic Effects
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.0E-01	Carcinogenic Effects				1.0E-01	Carcinogenic Effects
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.0E-01	Carcinogenic Effects				1.0E-01	Carcinogenic Effects
DICHLOROETHANE, 1,1-	5.0E+00	Cal DHS Primary MCL	5.0E+00			6.1E+00	Carcinogenic Effects
DICHLOROETHANE, 1,2-	5.0E-01	Cal DHS Primary MCL	5.0E-01	4.0E-01	Cal OEHHA PHG	7.4E-01	Carcinogenic Effects
DICHLOROETHYLENE, 1,1-	6.0E+00	Cal DHS Primary MCL	6.0E+00	1.0E+01	Cal OEHHA PHG	3.5E+01	Noncarcinogenic Effects
DICHLOROETHYLENE, Cis 1,2-	6.0E+00	Cal DHS Primary MCL	6.0E+00	1.0E+02	Cal OEHHA PHG	7.0E+01	Noncarcinogenic Effects
DICHLOROETHYLENE, Trans 1,2-	1.0E+01	Cal DHS Primary MCL	1.0E+01	6.0E+01	Cal OEHHA PHG	1.4E+02	Noncarcinogenic Effects
DICHLOROPHENOL, 2,4-	2.1E+01	Noncarcinogenic Effects				2.1E+01	Noncarcinogenic Effects
DICHLOROPROPANE, 1,2-	5.0E+00	Cal DHS Primary MCL	5.0E+00	5.0E-01	Cal OEHHA PHG	9.7E-01	Carcinogenic Effects
DICHLOROPROPENE, 1,3-	5.0E-01	Cal DHS Primary MCL	5.0E-01	2.0E-01	Cal OEHHA PHG	3.8E-01	Carcinogenic Effects
DIELDRIN	2.2E-03	Carcinogenic Effects				2.2E-03	Carcinogenic Effects
DIETHYLPHTHALATE	5.6E+03	Noncarcinogenic Effects				5.6E+03	Noncarcinogenic Effects
DIMETHYLPHTHALATE	7.0E+04	Noncarcinogenic Effects				7.0E+04	Noncarcinogenic Effects
DIMETHYLPHENOL, 2,4-	1.0E+02	Cal DHS AL		1.0E+02	Cal DHS AL	1.4E+02	Noncarcinogenic Effects
DINITROPHENOL, 2,4-	1.4E+01	Noncarcinogenic Effects				1.4E+01	Noncarcinogenic Effects
DINITROTOLUENE, 2,4-	1.1E-01	Carcinogenic Effects				1.1E-01	Carcinogenic Effects
1,4 DIOXANE	3.0E+00	Cal OEHHA PHG		3.0E+00	Cal OEHHA PHG	1.3E+00	Carcinogenic Effects
DIOXIN (2,3,7,8-TCDD)	3.0E-05	Cal DHS Primary MCL	3.0E-05			2.7E-07	Carcinogenic Effects
ENDOSULFAN	4.2E+01	Noncarcinogenic Effects				4.2E+01	Noncarcinogenic Effects
ENDRIN	2.0E+00	Cal DHS Primary MCL	2.0E+00	1.8E+00	Cal OEHHA PHG	2.1E+00	Noncarcinogenic Effects
ETHANOL		Not available					
ETHYLBENZENE	7.0E+02	Cal DHS Primary MCL	7.0E+02	3.0E+02	Cal OEHHA PHG	7.0E+02	Noncarcinogenic Effects
FLUORANTHENE	2.8E+02	Noncarcinogenic Effects				2.8E+02	Noncarcinogenic Effects
FLUORENE	2.8E+02	Noncarcinogenic Effects				2.8E+02	Noncarcinogenic Effects
HEPTACHLOR	1.0E-02	Cal DHS Primary MCL	1.0E-02	8.0E-03	Cal OEHHA PHG	8.5E-03	Carcinogenic Effects
HEPTACHLOR EPOXIDE	1.0E-02	Cal DHS Primary MCL	1.0E-02	6.0E-03	Cal OEHHA PHG	6.4E-03	Carcinogenic Effects

TABLE F-3. SUMMARY OF DRINKING WATER SCREENING LEVELS FOR HUMAN TOXICITY
(ug/L)

CHEMICAL PARAMETER	Final Screening Level	Basis	Cal DHS Primary MCL	Other CalEPA Criteria	Reference	*Risk-Based Goals (Drinking Water Toxicity)	Basis
HEXACHLOROBENZENE	1.0E+00	Cal DHS Primary MCL	1.0E+00			1.9E-02	Carcinogenic Effects
HEXACHLOROBUTADIENE	2.1E-01	Noncarcinogenic Effects				2.1E-01	Noncarcinogenic Effects
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	2.0E-01	Cal DHS Primary MCL	2.0E-01			3.2E-02	Carcinogenic Effects
HEXACHLOROETHANE	7.0E-01	Noncarcinogenic Effects				7.0E-01	Noncarcinogenic Effects
INDENO(1,2,3-cd)PYRENE	2.9E-02	Carcinogenic Effects				2.9E-02	Carcinogenic Effects
LEAD	1.5E+01	Cal DHS Primary MCL	1.5E+01	2.0E+00	Cal OEHHA PHG	-	-
MERCURY	2.0E+00	Cal DHS Primary MCL	2.0E+00	1.2E+00	Cal OEHHA PHG	2.1E+00	Noncarcinogenic Effects
METHOXYCHLOR	4.0E+01	Cal DHS Primary MCL	4.0E+01	3.0E+01	Cal OEHHA PHG	3.5E+01	Noncarcinogenic Effects
METHYLENE CHLORIDE	5.0E+00	Cal DHS Primary MCL	5.0E+00	4.0E+00	Cal OEHHA PHG	2.5E+00	Carcinogenic Effects
METHYL ETHYL KETONE	4.2E+03	Noncarcinogenic Effects				4.2E-03	Noncarcinogenic Effects
METHYL ISOBUTYL KETONE	1.2E+02	Cal DHS AL		1.2E+02	Cal DHS AL	5.6E+02	Noncarcinogenic Effects
METHYL MERCURY	7.0E-02	Noncarcinogenic Effects				7.0E-02	Noncarcinogenic Effects
METHYLNAPHTHALENE (total 1- & 2-)	2.8E+02	Noncarcinogenic Effects				2.8E+02	Noncarcinogenic Effects
METHYL TERT BUTYL ETHER	1.3E+01	Cal OEHHA		1.3E+01	Cal OEHHA	1.9E+01	Carcinogenic Effects
MOLYBDENUM	3.5E+01	Noncarcinogenic Effects				3.5E+01	Noncarcinogenic Effects
NAPHTHALENE	1.7E+01	Cal DHS AL		1.7E+01	Cal DHS AL	2.9E-01	Carcinogenic Effects
NICKEL	1.0E+02	Cal DHS Primary MCL	1.0E+02	1.2E+01	Cal OEHHA PHG	1.4E+02	Noncarcinogenic Effects
PENTACHLOROPHENOL	1.0E+00	Cal DHS Primary MCL	1.0E+00	4.0E-01	Cal OEHHA PHG	4.3E-01	Carcinogenic Effects
PERCHLORATE	6.0E+00	Cal OEHHA PHG		6.0E+00	Cal OEHHA PHG	7.0E-01	Noncarcinogenic Effects
PHENANTHRENE	2.8E+02	Noncarcinogenic Effects				2.8E+02	Noncarcinogenic Effects
PHENOL	4.2E+03	Cal DHS AL		4.2E+03	Cal DHS AL	2.1E+03	Noncarcinogenic Effects
POLYCHLORINATED BIPHENYLS (PCBs)	5.0E-01	Cal DHS Primary MCL	5.0E-01			1.8E-02	Carcinogenic Effects
PYRENE	2.1E+02	Noncarcinogenic Effects				2.1E+02	Noncarcinogenic Effects
SELENIUM	5.0E+01	Cal DHS Primary MCL	5.0E+01			3.5E+01	Noncarcinogenic Effects
SILVER	1.0E+02	Cal DHS Primary MCL	1.0E+02			3.5E+01	Noncarcinogenic Effects
STYRENE	1.0E+02	Cal DHS Primary MCL	1.0E+02			1.4E+02	Noncarcinogenic Effects
tert-BUTYL ALCOHOL	1.2E+01	Carcinogenic Effects				1.2E+01	Carcinogenic Effects
TETRACHLOROETHANE, 1,1,1,2-	1.3E+00	Carcinogenic Effects				1.3E+00	Carcinogenic Effects
TETRACHLOROETHANE, 1,1,2,2-	1.0E+00	Cal DHS Primary MCL	1.0E+00			1.3E-01	Carcinogenic Effects
TETRACHLOROETHYLENE	5.0E+00	Cal DHS Primary MCL	5.0E+00	6.0E-02	Cal OEHHA PHG	6.5E-02	Carcinogenic Effects
THALLIUM	2.0E+00	Cal DHS Primary MCL	2.0E+00	1.0E-01	Cal OEHHA PHG	4.6E-01	Noncarcinogenic Effects
TOLUENE	1.5E+02	Cal DHS Primary MCL	1.5E+02	1.5E+02	Cal OEHHA PHG	1.4E+03	Noncarcinogenic Effects
TOXAPHENE	3.0E+00	Cal DHS Primary MCL	3.0E+00			2.9E-02	Carcinogenic Effects
TPH (gasolines)	2.1E+02	Noncarcinogenic Effects				2.1E+02	Noncarcinogenic Effects
TPH (middle distillates)	2.1E+02	Noncarcinogenic Effects				2.1E+02	Noncarcinogenic Effects
TPH (residual fuels)	2.1E+02	Noncarcinogenic Effects				2.1E+02	Noncarcinogenic Effects
TRICHLOROBENZENE, 1,2,4-	7.0E+01	Cal DHS Primary MCL	7.0E+01	5.0E+00	Cal OEHHA PHG	9.7E+00	Carcinogenic Effects

TABLE F-3. SUMMARY OF DRINKING WATER SCREENING LEVELS FOR HUMAN TOXICITY
(ug/L)

CHEMICAL PARAMETER	Final Screening Level	Basis	Cal DHS Primary MCL	Other CalEPA Criteria	Reference	*Risk-Based Goals (Drinking Water Toxicity)	Basis
TRICHLOROETHANE, 1,1,1-	2.0E+02	Cal DHS Primary MCL	2.0E+02	1.0E+03	Cal OEHHA PHG	2.0E+03	Noncarcinogenic Effects
TRICHLOROETHANE, 1,1,2-	5.0E+00	Cal DHS Primary MCL	5.0E+00	2.0E-01	Cal OEHHA PHG	4.9E-01	Carcinogenic Effects
TRICHLOROETHYLENE	5.0E+00	Cal DHS Primary MCL	5.0E+00	8.0E-01	Cal OEHHA PHG	2.1E+00	Noncarcinogenic Effects
TRICHLOROPHENOL, 2,4,5-	7.0E+02	Noncarcinogenic Effects				7.0E+02	Noncarcinogenic Effects
TRICHLOROPHENOL, 2,4,6-	5.0E-01	Carcinogenic Effects				5.0E-01	Carcinogenic Effects
VANADIUM	1.5E+01	Cal DHS AL		1.5E+01	Cal DHS AL	4.9E+01	Noncarcinogenic Effects
VINYL CHLORIDE	5.0E-01	Cal DHS Primary MCL	5.0E-01	5.0E-02	Cal OEHHA PHG	1.3E-01	Carcinogenic Effects
XYLENES	1.8E+03	Cal DHS Primary MCL	1.8E+03	1.8E+03	Cal OEHHA PHG	1.4E+03	Noncarcinogenic Effects
ZINC	5.0E+03	Cal DHS Primary MCL	5.0E+03			2.1E+03	Noncarcinogenic Effects

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Source (unless otherwise noted):
A Compilation of Water Quality Goals (August 2003 and updates), CalEPA RWQCB - Central Valley Region (CRWQCBCV 2003)

Notes:
Used for development of groundwater and soil screening levels.
TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
Final health-based screening level for drinking water: Cal EPA Primary MCL or, in order of preference and availability, CalEPA Public Health Goal, Cal DHS Action Level and risk-based goal.
Cal DHS MCL: California EPA Department of Health Services Maximum Concentration Level.
OEHHA PHG: California Office of Environmental Health Hazard Assessment Public Health Goal.
Cal DHS AL: California Department of Health Services Action Level based on toxicity to humans.
*Risk-based goals calculated using Cal DHS model as presented in A Compilation of Water Quality Goals (August 2003).
Calculated goals for carcinogenic effects based on target excess cancer risk of 10^-6 (see Chapter 2 of text).
Calculated goals for noncarcinogenic effects based on relative source contribution factor of 20% (see Chapter 2 of text).

TABLE F-4a. SUMMARY OF SELECTED CHRONIC AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	[1]Lowest Estuary Aquatic Habitat Goal	Basis	Lowest Freshwater Aquatic Habitat Goal	Basis	Lowest Marine Aquatic Habitat Goal	Basis
ACENAPHTHENE	2.3E-01	USEPA Ecotox FW Chronic	2.3E+01	USEPA Ecotox FW Chronic	4.0E+01	USEPA Ecotox SW Chronic
ACENAPHTHYLENE	3.0E+01	10% USEPA SW Acute LOEL	3.0E+01	10% USEPA SW Acute LOEL	3.0E+01	10% USEPA SW Acute LOEL
ACETONE	1.5E+03	USDOE FW Chronic PRG	1.5E+03	USDOE FW Chronic PRG	1.5E+03	USDOE FW Chronic PRG
ALDRIN	1.3E-01	10% CTR SW CMC	3.0E-01	10% CTR FW CMC	1.3E-01	10% CTR SW CMC
ANTHRACENE	7.3E-01	USDOE FW Chronic PRG	7.3E-01	USDOE FW Chronic PRG	7.3E-01	USDOE FW Chronic PRG
ANTIMONY	3.0E+01	USEPA FW CCC	3.0E+01	USEPA FW CCC	5.0E+02	USEPA SW CCC
ARSENIC	3.6E+01	CTR SW CCC	1.5E+02	CTR FW CCC	3.6E+01	CTR SW CCC
BARIUM	1.0E+03	=Drinking Water (Table F-3)	1.0E+03	=Drinking Water (Table F-3)	1.0E+03	=Drinking Water (Table F-3)
BENZENE	4.6E+01	USEPA Ecotox FW Chronic	4.6E+01	USEPA Ecotox FW Chronic	3.5E+02	50% USEPA SW Chronic LOEL
BENZO(a)ANTHRACENE	2.7E-02	USDOE FW Chronic PRG	2.7E-02	USDOE FW Chronic PRG	2.7E-02	USDOE FW Chronic PRG
BENZO(b)FLUORANTHENE	2.9E-02	=Drinking Water (Table F-3)	2.9E-02	=Drinking Water (Table F-3)	2.9E-02	=Drinking Water (Table F-3)
BENZO(k)FLUORANTHENE	3.7E+00	50% MOEE FW Chronic LOEL	3.7E+00	50% MOEE FW Chronic LOEL	3.7E+00	50% MOEE FW Chronic LOEL
BENZO(g,h,i)PERYLENE	1.0E-01	50% MOEE FW Chronic LOEL	1.0E-01	50% MOEE FW Chronic LOEL	1.0E-01	50% MOEE FW Chronic LOEL
BENZO(a)PYRENE	1.4E-02	USEPA Ecotox FW Chronic	1.4E-02	USEPA Ecotox FW Chronic	1.4E-02	USEPA Ecotox FW Chronic
BERYLLIUM	2.7E+00	50% USEPA FW Chronic LOEL	2.7E+00	50% USEPA FW Chronic LOEL	2.7E+00	50% USEPA FW Chronic LOEL
BIPHENYL, 1,1-	1.4E+01	USEPA Ecotox FW Chronic	1.4E+01	USEPA Ecotox FW Chronic	1.4E+01	USEPA Ecotox FW Chronic
BIS(2-CHLOROETHYL)ETHER	6.1E+01	50% USEPA FW Chronic LOEL	6.1E+01	50% USEPA FW Chronic LOEL	6.1E+01	50% USEPA FW Chronic LOEL
BIS(2-CHLOROISOPROPYL)ETHER	6.1E+01	50% USEPA FW Chronic LOEL	6.1E+01	50% USEPA FW Chronic LOEL	6.1E+01	50% USEPA FW Chronic LOEL
BIS(2-ETHYLHEXYL)PHTHALATE	3.2E+01	USEPA Ecotox FW Chronic	3.2E+01	USEPA Ecotox FW Chronic	3.2E+01	USEPA Ecotox FW Chronic
BORON	1.6E+00	USDOE FW Chronic PRG	1.6E+00	USDOE FW Chronic PRG	1.6E+00	USDOE FW Chronic PRG
BROMODICHLOROMETHANE	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL
BROMOFORM	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL
BROMOMETHANE	1.6E+02	50% MOEE FW Chronic LOEL	1.6E+02	50% MOEE FW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL
CADMIUM	1.1E+00	RWQCBSF Basin Plan	1.1E+00	RWQCBSF Basin Plan	9.3E+00	RWQCBSF Basin Plan
CARBON TETRACHLORIDE	9.8E+00	USDOE FW Chronic PRG	9.8E+00	USDOE FW Chronic PRG	3.2E+03	50% USEPA SW Chronic LOEL
CHLORDANE	4.0E-03	CTR SW CCC	4.3E-03	CTR FW CCC	4.0E-03	CTR SW CCC
CHLOROANILINE, p-	5.0E+00	50% MOEE FW Chronic LOEL	5.0E+00	50% MOEE FW Chronic LOEL	5.0E+00	50% MOEE FW Chronic LOEL
CHLOROBENZENE	2.5E+01	50% USEPA FW Chronic LOEL	2.5E+01	50% USEPA FW Chronic LOEL	6.5E+01	50% USEPA SW Chronic LOEL
CHLOROETHANE	1.2E+01	=Drinking Water (Table F-3)	1.2E+01	=Drinking Water (Table F-3)	1.2E+01	=Drinking Water (Table F-3)
CHLOROFORM	6.2E+02	50% USEPA FW Chronic LOEL	6.2E+02	50% USEPA FW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL
CHLOROMETHANE	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL
CHLOROPHENOL, 2-	4.4E+02	10% USEPA FW Acute LOEL	4.4E+02	10% USEPA FW Acute LOEL	4.4E+02	10% USEPA FW Acute LOEL
CHROMIUM (Total)	1.8E+02	=Cr III	1.8E+02	CTR FW CCC	1.8E+02	CTR FW CCC
CHROMIUM III	1.8E+02	CTR FW CCC	1.8E+02	CTR FW CCC	1.8E+02	CTR FW CCC
CHROMIUM VI	1.1E+01	CTR FW CCC	1.1E+01	CTR FW CCC	5.0E+01	CTR SW CCC
CHRYSENE	3.5E-01	50% MOEE FW Chronic LOEL	3.5E-01	50% MOEE FW Chronic LOEL	3.5E-01	50% MOEE FW Chronic LOEL
COBALT	3.0E+00	USEPA Ecotox FW Chronic	3.0E+00	USEPA Ecotox FW Chronic	3.0E+00	USEPA Ecotox FW Chronic
COPPER	3.1E+00	CTR SW CCC	9.0E+00	CTR FW CCC	3.1E+00	CTR SW CCC
CYANIDE (Free)	1.0E+00	CTR SW CCC	5.2E+00	CTR FW CCC	1.0E+00	CTR SW CCC
DIBENZO(a,h)ANTHTRACENE	7.5E+00	50% MOEE FW Chronic LOEL	7.5E+00	50% MOEE FW Chronic LOEL	7.5E+00	50% MOEE FW Chronic LOEL

TABLE F-4a. SUMMARY OF SELECTED CHRONIC AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Aquatic Habitat Goals					
	[1]Lowest Estuary Aquatic Habitat Goal	Basis	Lowest Freshwater Aquatic Habitat Goal	Basis	Lowest Marine Aquatic Habitat Goal	Basis
DIBROMOCHLOROMETHANE	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL	3.2E+03	50% USEPA SW Chronic LOEL
1,2-DIBROMO-3-CHLOROPROPANE	2.0E-01	=Drinking Water (Table F-3)	2.0E-01	=Drinking Water (Table F-3)	2.0E-01	=Drinking Water (Table F-3)
DIBROMOETHANE, 1,2-	1.4E+03	50% MOEE FW Chronic AWQC	1.4E+03	50% MOEE FW Chronic AWQC	1.4E+03	50% MOEE FW Chronic AWQC
DICHLOROBENZENE, 1,2-	1.4E+01	USEPA Ecotox FW Chronic	1.4E+01	USEPA Ecotox FW Chronic	6.5E+01	50% USEPA SW Chronic LOEL
DICHLOROBENZENE, 1,3-	6.5E+01	50% USEPA SW Chronic LOEL	7.1E+01	USEPA Ecotox FW Chronic	6.5E+01	50% USEPA SW Chronic LOEL
DICHLOROBENZENE, 1,4-	1.5E+01	USEPA Ecotox FW Chronic	1.5E+01	USEPA Ecotox FW Chronic	6.5E+01	50% USEPA SW Chronic LOEL
DICHLOROBENZIDINE, 3,3-	2.5E+02	50% MOEE FW Chronic LOEL	2.5E+02	50% MOEE FW Chronic LOEL	2.5E+02	50% MOEE FW Chronic LOEL
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.0E-03	=DDT	1.0E-03	=DDT	1.0E-03	=DDT
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.0E-03	=DDT	1.0E-03	=DDT	1.0E-03	=DDT
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.0E-03	CTR FW/SW CCC	1.0E-03	CTR FW CCC	1.0E-03	CTR SW CCC
DICHLOROETHANE, 1,1-	4.7E+01	USEPA Ecotox FW Chronic	4.7E+01	USEPA Ecotox FW Chronic	4.7E+01	USEPA Ecotox FW Chronic
DICHLOROETHANE, 1,2-	1.0E+04	50% USEPA FW Chronic LOEL	1.0E+04	50% USEPA FW Chronic LOEL	1.0E+04	50% USEPA FW Chronic LOEL
DICHLOROETHYLENE, 1,1-	2.5E+01	USDOE FW Chronic PRG	2.5E+01	USDOE FW Chronic PRG	2.5E+01	USDOE FW Chronic PRG
DICHLOROETHYLENE, Cis 1,2-	5.9E+02	USDOE FW Chronic PRG	5.9E+02	USDOE FW Chronic PRG	5.9E+02	USDOE FW Chronic PRG
DICHLOROETHYLENE, Trans 1,2-	5.9E+02	USDOE FW Chronic PRG	5.9E+02	USDOE FW Chronic PRG	5.9E+02	USDOE FW Chronic PRG
DICHLOROPHENOL, 2,4-	1.8E+02	50% USEPA FW Chronic LOEL	1.8E+02	50% USEPA FW Chronic LOEL	1.8E+02	50% USEPA FW Chronic LOEL
DICHLOROPROPANE, 1,2-	1.5E+03	50% USEPA SW Chronic LOEL	2.9E+03	50% USEPA FW Chronic LOEL	1.5E+03	50% USEPA SW Chronic LOEL
DICHLOROPROPENE, 1,3-	1.2E+02	50% USEPA FW Chronic LOEL	1.2E+02	50% USEPA FW Chronic LOEL	1.2E+02	50% USEPA FW Chronic LOEL
DIELDRIN	1.9E-03	CTR SW CCC	5.6E-02	CTR FW CCC	1.9E-03	CTR SW CCC
DIETHYLPHTHALATE	1.5E+00	50% USEPA FW Chronic LOEL	1.5E+00	50% USEPA FW Chronic LOEL	1.7E+00	50% USEPA SW Chronic LOEL
DIMETHYLPHTHALATE	1.5E+00	50% USEPA FW Chronic LOEL	1.5E+00	50% USEPA FW Chronic LOEL	1.7E+00	50% USEPA SW Chronic LOEL
DIMETHYLPHENOL, 2,4-	1.1E+02	USEPA SW CCC	5.3E+02	USEPA FW CCC	1.1E+02	USEPA SW CCC
DINITROPHENOL, 2,4-	7.5E+01	50% USEPA FW Chronic LOEL	7.5E+01	50% USEPA FW Chronic LOEL	7.5E+01	50% USEPA FW Chronic LOEL
DINITROTOLUENE, 2,4-	1.2E+02	50% USEPA FW Chronic LOEL	1.2E+02	50% USEPA FW Chronic LOEL	1.9E+02	50% USEPA SW Chronic LOEL
1,4 DIOXANE	3.4E+05	5% Acute FW LC 50	3.4E+05	5% Acute FW LC 50	5.0E+05	5% acute FW LC 50
DIOXIN (2,3,7,8-TCDD)	5.0E-06	50% USEPA FW Chronic LOEL	5.0E-06	50% USEPA FW Chronic LOEL	5.0E-06	50% USEPA FW Chronic LOEL
ENDOSULFAN	8.7E-03	CTR SW CCC	5.6E-02	CTR FW CCC	8.7E-03	CTR SW CCC
ENDRIN	2.3E-03	CTR SW CCC	3.6E-02	CTR FW CCC	2.3E-03	CTR SW CCC
ETHANOL						
ETHYLBENZENE	2.9E+02	USEPA Ecotox FW Chronic	2.9E+02	USEPA Ecotox FW Chronic	2.9E+02	USEPA Ecotox FW Chronic
FLUORANTHENE	8.0E+00	50% USEPA SW Chronic LOEL	8.1E+00	USEPA Ecotox FW Chronic	8.0E+00	50% USEPA SW Chronic LOEL
FLUORENE	3.9E+00	USEPA Ecotox FW Chronic	3.9E+00	USEPA Ecotox FW Chronic	3.9E+00	USEPA Ecotox FW Chronic
HEPTACHLOR	3.8E-03	CTR FW CCC	3.8E-03	CTR FW CCC	0.0036	CTR SW CCC
HEPTACHLOR EPOXIDE	3.8E-03	CTR FW CCC	3.8E-03	CTR FW CCC	0.0036	CTR SW CCC
HEXACHLOROBENZENE	3.7E+00	USEPA FW CCC	3.7E+00	USEPA FW CCC	6.5E+01	50% USEPA SW Chronic LOEL
HEXACHLOROBUTADIENE	4.7E+00	50% USEPA FW Chronic LOEL	4.7E+00	50% USEPA FW Chronic LOEL	4.7E+00	50% USEPA FW Chronic LOEL
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	8.0E-02	USEPA Ecotox FW Chronic	8.0E-02	USEPA Ecotox FW Chronic	8.0E-02	USEPA Ecotox FW Chronic
HEXACHLOROETHANE	1.2E+01	USEPA Ecotox FW Chronic	1.2E+01	USEPA Ecotox FW Chronic	1.2E+01	USEPA Ecotox FW Chronic
INDENO(1,2,3-cd)PYRENE	2.9E-02	=Drinking Water (Table F-3)	2.9E-02	=Drinking Water (Table F-3)	2.9E-02	=Drinking Water (Table F-3)
LEAD	2.5E+00	CTR FW CCC	2.5E+00	CTR FW CCC	8.1E+00	CTR SW CCC

TABLE F-4a. SUMMARY OF SELECTED CHRONIC AQUATIC HABITAT GOALS
(ug/l)

	Aquatic Habitat Goals					
CHEMICAL PARAMETER	[1] Lowest Estuary Aquatic Habitat Goal	Basis	Lowest Freshwater Aquatic Habitat Goal	Basis	Lowest Marine Aquatic Habitat Goal	Basis
MERCURY	1.2E-02	RWQCBSF Basin Plan	1.2E-02	RWQCBSF Basin Plan	2.5E-02	RWQCBSF Basin Plan
METHOXYCHLOR	1.9E-02	USEPA Ecotox FW Chronic	1.9E-02	USEPA Ecotox FW Chronic	1.9E-02	USEPA Ecotox FW Chronic
METHYLENE CHLORIDE	2.2E+03	USDOE FW Chronic PRG	2.2E+03	USDOE FW Chronic PRG	3.2E+03	50% USEPA SW Chronic LOEL
METHYL ETHYL KETONE	1.4E+04	USDOE FW Chronic PRG	1.4E+04	USDOE FW Chronic PRG	1.4E+04	USDOE FW Chronic PRG
METHYL ISOBUTYL KETONE	1.7E+02	USDOE FW Chronic PRG	1.7E+02	USDOE FW Chronic PRG	1.7E+02	USDOE FW Chronic PRG
METHYL MERCURY	3.0E-03	USEPA Ecotox FW Chronic	3.0E-03	USEPA Ecotox FW Chronic	3.0E-03	USEPA Ecotox FW Chronic
METHYLNAPHTHALENE (total 1- & 2-)	2.1E+00	USDOE FW Chronic PRG	2.1E+00	USDOE FW Chronic PRG	2.1E+00	USDOE FW Chronic PRG
METHYL TERT BUTYL ETHER	8.0E+03	CTR SW CCC	6.6E+04	CTR FW CCC	8.0E+03	CTR SW CCC
MOLYBDENUM	2.4E+02	USEPA Ecotox FW Chronic	2.4E+02	USEPA Ecotox FW Chronic	2.4E+02	USEPA Ecotox FW Chronic
NAPHTHALENE	2.4E+01	USEPA Ecotox FW Chronic	2.4E+01	USEPA Ecotox FW Chronic	2.4E+01	USEPA Ecotox FW Chronic
NICKEL	8.2E+00	CTR SW CCC	5.2E+01	CTR FW CCC	8.2E+00	CTR SW CCC
PENTACHLOROPHENOL	7.9E+00	CTR SW CCC	1.5E+01	CTR FW CCC	7.9E+00	CTR SW CCC
PERCHLORATE	6.0E+02	USEPA Ecotox FW Chronic	6.0E+02	USEPA Ecotox FW Chronic	6.0E+02	USEPA Ecotox FW Chronic
PHENANTHRENE	4.6E+00	USEPA SW CCC	6.3E+00	USEPA FW CCC	4.6E+00	USEPA SW CCC
PHENOL	1.3E+03	50% USEPA FW Chronic LOEL	1.3E+03	50% USEPA FW Chronic LOEL	1.3E+03	50% USEPA FW Chronic LOEL
POLYCHLORINATED BIPHENYLS (PCBs)	1.4E-02	CTR FW CCC	1.4E-02	CTR FW CCC	3.0E-02	CTR SW CCC
PYRENE	2.0E+00	50% MOEE FW Chronic LOEL	2.0E+00	50% MOEE FW Chronic LOEL	2.0E+00	50% MOEE FW Chronic LOEL
SELENIUM	5.0E+00	CTR FW CCC	5.0E+00	CTR FW CCC	7.1E+01	CTR SW CCC
SILVER	1.9E-01	10% CTR SW CMC	3.4E-01	10% CTR FW CMC	1.9E-01	10% CTR SW CMC
STYRENE	1.0E+02	=Drinking Water (Table F-3)	1.0E+02	=Drinking Water (Table F-3)	1.0E+02	=Drinking Water (Table F-3)
tert-BUTYL ALCOHOL	1.8E+04	10% Acute FW LC 0	1.8E+04	10% Acute FW LC 0	1.8E+04	10% Acute FW LC 0
TETRACHLOROETHANE, 1,1,1,2-	9.3E+02	10% USEPA FW Acute LOEL	9.3E+02	10% USEPA FW Acute LOEL	9.3E+02	10% USEPA FW Acute LOEL
TETRACHLOROETHANE, 1,1,2,2-	4.2E+02	USEPA Ecotox FW Chronic	4.2E+02	USEPA Ecotox FW Chronic	4.2E+02	USEPA Ecotox FW Chronic
TETRACHLOROETHYLENE	1.2E+02	USEPA Ecotox FW Chronic	1.2E+02	USEPA Ecotox FW Chronic	2.3E+02	50% USEPA SW Chronic LOEL
THALLIUM	2.0E+01	50% USEPA FW Chronic LOEL	2.0E+01	50% USEPA FW Chronic LOEL	2.0E+01	50% USEPA FW Chronic LOEL
TOLUENE	1.3E+02	USEPA Ecotox FW Chronic	1.3E+02	USEPA Ecotox FW Chronic	2.5E+03	50% USEPA SW Chronic LOEL
TOXAPHENE	2.0E-04	CTR FW/SW CCC	2.0E-04	CTR FW CCC	2.0E-04	CTR SW CCC
TPH (gasolines)	5.0E+02	RWQCBSF (see notes)	5.0E+02	RWQCBSF (see notes)	3.7E+03	RWQCBSF (see notes)
TPH (middle distillates)	6.4E+02	RWQCBSF (see notes)	6.4E+02	RWQCBSF (see notes)	6.4E+02	RWQCBSF (see notes)
TPH (residual fuels)	6.4E+02	RWQCBSF (see notes)	6.4E+02	RWQCBSF (see notes)	6.4E+02	RWQCBSF (see notes)
TRICHLOROBENZENE, 1,2,4-	2.5E+01	50% USEPA FW Chronic LOEL	2.5E+01	50% USEPA FW Chronic LOEL	6.5E+01	50% USEPA SW Chronic LOEL
TRICHLOROETHANE, 1,1,1-	6.2E+01	USEPA Ecotox FW Chronic	6.2E+01	USEPA Ecotox FW Chronic	6.2E+01	USEPA Ecotox FW Chronic
TRICHLOROETHANE, 1,1,2-	4.7E+03	50% USEPA FW Chronic LOEL	4.7E+03	50% USEPA FW Chronic LOEL	4.7E+03	50% USEPA FW Chronic LOEL
TRICHLOROETHYLENE	3.6E+02	USEPA Ecotox FW Chronic	3.6E+02	USEPA Ecotox FW Chronic	3.6E+02	USEPA Ecotox FW Chronic
TRICHLOROPHENOL, 2,4,5-	1.1E+01	USEPA SW CCC	6.3E+01	USEPA FW CCC	1.1E+01	USEPA SW CCC
TRICHLOROPHENOL, 2,4,6-	4.9E+02	50% USEPA FW Chronic LOEL	4.9E+02	50% USEPA FW Chronic LOEL	4.9E+02	50% USEPA FW Chronic LOEL
VANADIUM	1.9E+01	USEPA Ecotox FW Chronic	1.9E+01	USEPA Ecotox FW Chronic	1.9E+01	USEPA Ecotox FW Chronic

TABLE F-4a. SUMMARY OF SELECTED CHRONIC AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Aquatic Habitat Goals					
	[1]Lowest Estuary Aquatic Habitat Goal	Basis	Lowest Freshwater Aquatic Habitat Goal	Basis	Lowest Marine Aquatic Habitat Goal	Basis
VINYL CHLORIDE	7.8E+02	USDOE FW Chronic PRG	7.8E+02	USDOE FW Chronic PRG	7.8E+02	USDOE FW Chronic PRG
XYLENES	1.0E+02	5% acute SW LC 50	1.0E+02	5% acute SW LC 50	1.0E+02	5% acute SW LC 50
ZINC	8.1E+01	CTR SW CCC	1.2E+02	CTR FW CCC	8.1E+01	CTR SW CCC

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

1. Lowest Estuary Goal = Lowest of Freshwater vs Marine chronic goals. Used for development of groundwater and soil screening levels.

Aquatic Habitat Goals: Addresses potential impact on freshwater or marine aquatic habitats. Final screening levels are lowest of marine and freshwater criteria.

See text for prioritization and selection of surface water quality screening levels. CTR HH criteria for potential bioaccumulation of chemicals in aquatic life considered in surface water screening levels only (refer to main text).

Drinking water goal substituted as aqautic habitat goal if later was not available (see text).

Review of aquatic ecotoxicty data for ethanol underway. Based on preliminary review of available data, chronic toxicity screening levels likely to be significantly greater than ceiling level of 50,000 ug/L (see Table I series). Refer to USEPA 2003b, ECOTOX database).

Methyl tert-Butyl Ether: Interim salt water CCC proposed by Region 2 Water Quality Control Board (RWQCBSF, 1998b)

TPH screening levels: Based on TPH screening levels published in RWQCB Board Orders. See footnotes for Table F-4b.

AWQC: Aquatic Water Quality Criteria

CCC: Criterion for Continuous Concentration

CMC: Criterion for Maximum Concentration

CTR: California (interim) Toxics Rule (in RWQCBCV 2000 and Federal Register 2000)

FCV: Final Chronic Value

FW: Freshwater

LOEL: Lowest Observed Effects Level

MOEE: Ontario Ministry of Environment and Energy (MOEE 1996)

PRG: USDOE Preliminary Remediation Goal for ecological concerns.

SW: Saltwater

TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

USDOE: U. S. Department of Energy

USEPA: U.S. Environmental Protection Agency

TABLE F-4b. SUMMARY OF CALIFORNIA
CONTINUOUS AND MAXIMUM AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Freshwater			Saltwater		
	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan
ACENAPHTHENE						
ACENAPHTHYLENE						
ACETONE						
ALDRIN		3.0E+00			1.3E+00	
ANTHRACENE						
ANTIMONY						
ARSENIC	1.5E+02	3.4E+02	1.9E+02	3.6E+01	6.9E+01	3.6E+01
BARIUM						
BENZENE						
BENZO(a)ANTHRACENE						
BENZO(b)FLUORANTHENE						
BENZO(k)FLUORANTHENE						
BENZO(g,h,i)PERYLENE						
BENZO(a)PYRENE						
BERYLLIUM						
BIPHENYL, 1,1-						
BIS(2-CHLOROETHYL)ETHER						
BIS(2-CHLOROISOPROPYL)ETHER						
BIS(2-ETHYLHEXYL)PHTHALATE						
BORON						
BROMODICHLOROMETHANE						
BROMOFORM						
BROMOMETHANE						
CADMIUM		3.9E+00	1.1E+00	9.3E+00	4.2E+01	9.3E+00
CARBON TETRACHLORIDE						
CHLORDANE	4.3E-03	2.4E+00		4.0E-03	9.0E-02	
CHLOROANILINE, p-						
CHLOROBENZENE						
CHLOROETHANE						
CHLOROFORM						
CHLOROMETHANE						
CHLOROPHENOL, 2-						
CHROMIUM (Total)	1.8E+02	5.5E+02				
CHROMIUM III	1.8E+02	5.5E+02				
CHROMIUM VI	1.1E+01	1.6E+01	1.1E+01	5.0E+01	1.1E+03	5.0E+01
CHRYSENE						
COBALT						
COPPER	9.0E+00	1.3E+01	6.5E+00	3.1E+00	4.8E+00	
CYANIDE (Free)	5.2E+00	2.2E+01		1.0E+00	1.0E+00	

TABLE F-4b. SUMMARY OF CALIFORNIA
CONTINUOUS AND MAXIMUM AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Freshwater			Saltwater		
	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan
DIBENZO(a,h)ANTHTRACENE						
DIBROMOCHLOROMETHANE						
1,2-DIBROMO-3-CHLOROPROPANE						
DIBROMOETHANE, 1,2-						
DICHLOROBENZENE, 1,2-						
DICHLOROBENZENE, 1,3-						
DICHLOROBENZENE, 1,4-						
DICHLOROBENZIDINE, 3,3-						
DICHLORODIPHENYLDICHLOROETHANE (DDD)						
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)						
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.0E-03	1.1E+00		1.0E-03	1.3E-01	
DICHLOROETHANE, 1,1-						
DICHLOROETHANE, 1,2-						
DICHLOROETHYLENE, 1,1-						
DICHLOROETHYLENE, Cis 1,2-						
DICHLOROETHYLENE, Trans 1,2-						
DICHLOROPHENOL, 2,4-						
DICHLOROPROPANE, 1,2-						
DICHLOROPROPENE, 1,3-						
DIELDRIN	5.6E-02	2.4E-01		1.9E-03	7.1E-01	
DIETHYLPHTHALATE						
DIMETHYLPHTHALATE						
DIMETHYLPHENOL, 2,4-						
DINITROPHENOL, 2,4-						
DINITROTOLUENE, 2,4-						
1,4 DIOXANE						
DIOXIN (2,3,7,8-TCDD)						
ENDOSULFAN	5.6E-02	2.2E-01		8.7E-03	3.4E-02	
ENDRIN	3.6E-02	8.6E-02		2.3E-03	3.7E-02	
ETHANOL						
ETHYLBENZENE						
FLUORANTHENE						
FLUORENE						
HEPTACHLOR	3.8E-03	5.2E-02		0.0036	5.3E-02	
HEPTACHLOR EPOXIDE	3.8E-03	5.2E-02		0.0036	5.3E-02	
HEXACHLOROBENZENE						
HEXACHLOROBUTADIENE						
HEXACHLOROCYCLOHEXANE (gamma) LINDANE		9.5E-01			1.6E-01	
HEXACHLOROETHANE						

TABLE F-4b. SUMMARY OF CALIFORNIA
CONTINUOUS AND MAXIMUM AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Freshwater			Saltwater		
	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan
INDENO(1,2,3-cd)PYRENE						
LEAD	2.5E+00	6.5E+01	3.2E+00	8.1E+00	2.1E+02	5.6E+00
MERCURY			1.2E-02			2.5E-02
METHOXYCHLOR						
METHYLENE CHLORIDE						
METHYL ETHYL KETONE						
METHYL ISOBUTYL KETONE						
METHYL MERCURY						
METHYLNAPHTHALENE (total 1- & 2-)						
METHYL TERT BUTYL ETHER	6.6E+04	1.2E+05		8.0E+03	1.4E+04	
MOLYBDENUM						
NAPHTHALENE						
NICKEL	5.2E+01	4.7E+02		8.2E+00	7.4E+01	
PENTACHLOROPHENOL	1.5E+01	1.9E+01		7.9E+00	1.3E+01	
PERCHLORATE						
PHENANTHRENE						
PHENOL						
POLYCHLORINATED BIPHENYLS (PCBs)	1.4E-02			3.0E-02		
PYRENE						
SELENIUM	5.0E+00			7.1E+01	2.9E+02	
SILVER		3.4E+00			1.9E+00	
STYRENE						
tert-BUTYL ALCOHOL						
TETRACHLOROETHANE, 1,1,1,2-						
TETRACHLOROETHANE, 1,1,2,2-						
TETRACHLOROETHYLENE						
THALLIUM						
TOLUENE						
TOXAPHENE	2.0E-04	7.3E-01		2.0E-04	2.1E-01	
TPH (gasolines)			5.0E+02			
TPH (middle distillates)			6.4E+02			
TPH (residual fuels)			6.4E+02			3.7E+03
TRICHLOROBENZENE, 1,2,4-						
TRICHLOROETHANE, 1,1,1-						
TRICHLOROETHANE, 1,1,2-						
TRICHLOROETHYLENE						
TRICHLOROPHENOL, 2,4,5-						
TRICHLOROPHENOL, 2,4,6-						
VANADIUM						

TABLE F-4b. SUMMARY OF CALIFORNIA
CONTINUOUS AND MAXIMUM AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Freshwater			Saltwater		
	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan	Criterion for Continuous Concentration	Criterion for Maximum Concentration	Region 2 Basin Plan
VINYL CHLORIDE						
XYLENES						
ZINC	1.2E+02	1.2E+02		8.1E+01	9.0E+01	

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

References:

Primary sources: 1) 40 CFR Part 131: Water Quality Standards; Establishment of Numerical Criteria for Priority Toxic Pollutants for the State of California: Federal Register (May 18, 2000). 2) Interim California Toxics Rule, as summarized in A Compilation of Water Quality Goals (August 2003), CalEPA RWQCB - Central Valley Region (CRWQCBCV 2003).

Notes:

Used for development of groundwater and soil screening levels.

See text for prioritization and selection of surface water quality screening levels. Criteria for potential bioaccumulation of chemicals in aquatic organism and subsequent human consumption considered separately (refer to Table F-4d and main text).

CCC: Criterion for Continuous Concentration

CMC: Criterion for Maximum Concentration

Cadmium: CTR CMC value removed in 2004. Value shown is acute freshwater goal for cadmium presented in 1995 Basin Plan.

Methyl tert-Butyl Ether: Interim aquatic surface water criteria proposed by Region 2 Water Quality Control Board (RWQCBSF, 1998a).

TPH screening levels: Gasoline freshwater screening level based on studies carried out for Presidio of San Francisco (RWQCBSF 1998b). Gasoline screening level for saltwater and diesel and residual fuels screening levels in general based on studies carried out for San Francisco Airport (RWQCB 1999b). See Appendix 1 text.

TABLE F-4c. SUMMARY OF USEPA AND OTHER PUBLISHED AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Freshwater USEPA CCC	Freshwater USEPA Chronic LOEL	Freshwater USEPA CMC	Freshwater USEPA Acute LOEL	Freshwater Ecotox Chronic Threshold (AWQC, FCV Or Tier II)	Freshwater Other	Freshwater Basis	Marine USEPA CCC	Marine USEPA Chronic LOEL	Marine USEPA CMC	Marine USEPA Acute LOEL	Marine Ecotox Chronic Threshold (AWQC, FCV Or Tier II)	Other Value	Other Basis
ACENAPHTHENE		5.2E+02		1.7E+03	2.3E+01				7.1E+02		9.7E+02	4.0E+01		
ACENAPHTHYLENE						1.5E+03	USDOE FW Chronic PRG				3.0E+02			
ACETONE														
ALDRIN			3.0E+00							1.3E+00				
ANTHRACENE						7.3E-01	USDOE FW Chronic PRG							
ANTIMONY	3.0E+01		8.8E+01					5.0E+02		1.5E+03				
ARSENIC	1.5E+02		3.4E+02		1.9E+02			3.6E+01		6.9E+01		3.6E+01		
BARIUM														
BENZENE				5.3E+03	4.6E+01				7.0E+02		5.1E+03			
BENZO(a)ANTHRACENE						2.7E-02	USDOE FW Chronic PRG							
BENZO(b)FLUORANTHENE						3.7E+00	50% MOEE FW Chronic LOEL							
BENZO(k)FLUORANTHENE						1.0E-01	50% MOEE FW Chronic LOEL							
BENZO(g,h,i)PERYLENE					1.4E-02									
BENZO(a)PYRENE					5.1E+00									
BERYLLIUM		5.3E+00		1.3E+02	1.4E+01									
BIPHENYL, 1,1														
BIS(2CHLOROETHYL)ETHER		1.2E+02		2.4E+05										
BIS(2CHLOROISOPROPYL)ETHER		1.2E+02		2.4E+05										
BIS(2ETHYLHEXYL)PHTHALATE					3.2E+01									
BORON						1.6E+00	USDOE FW Chronic PRG							
BROMODICHLOROMETHANE				1.1E+04					6.4E+03		1.2E+04			
BROMOFORM				1.1E+04					6.4E+03		1.2E+04			
BROMOMETHANE				1.1E+04	1.0E+00	1.6E-02	50% MOEE FW Chronic LOEL		6.4E+03		1.2E+04	9.3E+00		
CADMIUM	2.5E-01		2.0E+00					8.8E+00		4.0E+01				
CARBON TETRACHLORIDE				3.5E+04		9.8E+00	USDOE FW Chronic PRG		6.4E+03		5.0E+04			
CHLORDANE	4.3E-03		2.4E+00					4.0E-03		9.0E-02				
CHLOROANILINE, p		5.0E+01		2.5E+02	1.3E+02									
CHLOROBENZENE						5.0E+00	50% MOEE FW Chronic LOEL		1.3E+02		1.6E+02			
CHLOROETHANE														
CHLOROFORM		1.2E+03		2.9E+04		2.8E-01	USDOE FW Chronic PRG		6.4E+03		1.2E+04			
CHLOROMETHANE				1.1E+04					6.4E+03		1.2E+04			
CHLOROPHENOL 2				4.4E+03		3.5E-01	50% MOEE FW Chronic LOEL							
CHROMIUM (Total)														
CHROMIUM III	7.4E+01		5.7E+02		1.8E+02						1.03E+04			
CHROMIUM VI	1.1E+01		1.6E+01		1.0E+01			5.0E+01		1.1E+03				
CHRYSENE														
COBALT					3.0E+00									
COPPER	9.0E+00		1.3E+01		1.1E+01			3.1E+00		4.8E+00		2.4E+00		
CYANIDE (Free)	5.2E+00		2.2E+01		5.2E+00					1.0E+00		1.0E+00		
DIBENZO(a,h)ANTHRACENE						7.5E+00	50% MOEE FW Chronic LOEL							
DIBROMOCHLOROMETHANE				1.1E+04					6.4E+03		1.2E+04			
1,2DIBROMO3CHLOROPROPANE						1.4E+03	50% MOEE FW Chronic AWQC							
DIBROMOETHANE, 1,2						2.5E-02	50% MOEE FW Chronic LOEL							
DICHLOROBENZENE, 1,2		7.6E+02		1.1E+03	1.4E+01				1.3E+02		1.97E+03			
DICHLOROBENZENE, 1,3		7.6E+02		1.1E+03	7.1E+01				1.3E+02		1.97E+03			
DICHLOROBENZENE, 1,4		7.6E+02		1.1E+03	1.5E+01				1.3E+02		1.97E+03			
DICHLOROBENZIDINE, 3,3														
DICHLORODIPHENYLDICHLOROETHANE (DDD)				6.0E-01		1.0E-03	=DDT				3.6E+00		1.0E-03	=DDT
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)				1.1E+03		1.0E-03	=DDT				1.4E+01		1.0E-03	=DDT
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.0E-03				1.3E-02			1.0E-03		1.3E-01				
DICHLOROETHANE, 1,1			1.1E+00		4.7E+01									
DICHLOROETHANE, 1,2		2.0E+04		1.2E+05		9.1E-02	USDOE FW Chronic PRG				1.13E+05			
DICHLOROETHYLENE, 1,1				1.2E+04		2.5E-01	USDOE FW Chronic PRG				2.24E+05			
DICHLOROETHYLENE, Cis 1,2				1.2E+04		5.9E+02	USDOE FW Chronic PRG				2.24E+05			
DICHLOROETHYLENE, Trans 1,2				1.2E+04		5.9E+02	USDOE FW Chronic PRG				2.24E+05			

TABLE F-4c. SUMMARY OF USEPA AND OTHER PUBLISHED AQUATIC HABITAT GOALS

(ug/l)

CHEMICAL PARAMETER	Freshwater							Marine					Other	
	USEPA CCC	USEPA Chronic LOEL	USEPA CMC	USEPA Acute LOEL	Ecotox Chronic Threshold (AWQC, FCV Or Tier II)	Other	Basis	USEPA CCC	USEPA Chronic LOEL	USEPA CMC	USEPA Acute LOEL	Ecotox Chronic Threshold (AWQC, FCV Or Tier II)	Value	Basis
DICHLOROPHENOL, 2,4		3.7E+02		2.0E+03										
DICHLOROPROPANE, 1,2		5.7E+03		2.3E+04					3.0E-03		1.03E+04			
DICHLOROPROPENE, 1,3		2.4E+02		6.1E+03							7.9E+02			
DIELDRIN	5.6E-02		2.4E-01		6.2E-02			1.9E-03		7.1E-01		1.1E-01		
DIETHYLPHTHALATE		3.0E+00		9.4E+02	2.2E+02				3.4E+00		2.94E+03			
DIMETHYLPHTHALATE		3.0E+00		9.4E+02					3.4E+00		2.94E+03			
DIMETHYLPHENOL, 2,4	5.3E+02		1.3E+03					1.1E-02						
DINITROPHENOL, 2,4		1.5E+02		2.3E+02							4.85E+03			
DINITROTOLUENE, 2,4		2.3E+02		3.3E+02					3.7E-02	2.7E-02	5.9E+02			
1,4 DIOXANE						3.4E+05	5% Acute FW LC 50						5.0E+05	5% acute FW LC 50
DIOXIN (2,3,7,8TCDD)		1.0E-05		1.0E-02										
ENDOSULFAN	5.6E-02		2.2E-01		5.6E-02			8.7E-03		3.4E-02				
ENDRIN	3.6E-02		8.6E-02		6.1E-02			2.3E-03		3.7E-02		1.0E-02		
ETHANOL														
ETHYLBENZENE				3.2E+04	2.9E+02						4.3E+02			
FLUORANTHENE				3.980E+03	8.1E+00				1.6E+01		4.0E+01	1.1E+01		
FLUORENE					3.9E+00						3.0E+02			
HEPTACHLOR	3.8E-03		5.2E-01		6.9E-03			3.6E-03		5.3E-02				
HEPTACHLOR EPOXIDE	3.8E-03		5.2E-01					3.6E-03		5.3E-02				
HEXACHLOROBENZENE	3.7E+00		6.0E+00						1.3E-02	1.6E-01	1.6E+02			
HEXACHLOROBUTADIENE		9.3E+01		9.0E+01	8.0E-02						3.2E+01			
HEXACHLOROCYCLOHEXANE (gamma) LINDANE			9.5E-01							1.6E-01				
HEXACHLOROETHANE		5.4E+02		9.8E+02	1.2E+01						9.4E+02			
INDENO(1,2,3cd)PYRENE														
LEAD	2.5E+00		6.5E+01		2.5E+00			8.1E+00		2.1E+02		8.1E+00		
MERCURY	7.7E-01		1.4E+00		1.3E+00			9.4E-01		1.8E+00		1.1E+00		
METHOXYCHLOR			3.0E-02		1.9E-02					3.0E-02				
METHYLENE CHLORIDE				1.1E+04		2.2E+03	USDOE FW Chronic PRG		6.4E+03		1.2E+04			
METHYL ETHYL KETONE						1.4E+04	USDOE FW Chronic PRG							
METHYL ISOBUTYL KETONE						1.7E+02	USDOE FW Chronic PRG							
METHYL MERCURY					3.0E-03	2.1E+00	USDOE FW Chronic PRG				3.0E-02			
METHYLNAPHTHALENE (total 1 & 2)		2.56E+03		1.02E+04										
METHYL TERT BUTYL ETHER														
MOLYBDENUM					2.4E+02									
NAPHTHALENE		6.2E+02		2.3E+03	2.4E+01						2.4E+03			
NICKEL	5.2E+01		4.7E+02		1.6E+02			8.2E+00		7.4E+01		8.2E+00		
PENTACHLOROPHENOL	1.5E+01		1.9E+01		1.3E+01			7.9E+00		1.3E+01		7.9E+00		
PERCHLORATE					6.0E+02									
PHENANTHRENE					6.3E+00			4.6E+00		7.7E+00		8.3E+00		
PHENOL	6.3E+00		3.0E+01	1.02E+04	1.9E-01						5.8E+03			
POLYCHLORINATED BIPHENYLS (PCBs)	1.4E-02							3.0E-02						
PYRENE														
SELENIUM	5.0E+00		3.2E+00		5.0E+00	2.0E+00	50% MOEE FW Chronic LOEL	7.1E+01		2.9E+02		7.1E+01		
SILVER			3.2E+00							1.9E+00				
STYRENE														
tert-BUTYL ALCOHOL						1.8E+04	10% Acute FW LC 0							
TETRACHLOROETHANE, 1,1,1,2		2.4E+03		9.32E+03	4.2E+02						9.02E+03			
TETRACHLOROETHANE, 1,1,2,2		8.4E+02		9.32E+03	1.2E+02									
TETRACHLOROETHYLENE		4.0E+01		5.28E+03					4.5E-02		1.02E+04			
THALLIUM				1.4E+03							2.13E+03			
TOLUENE				1.75E+04	1.3E+02				5.0E-03		6.3E+03			
TOXAPHENE	2.0E-04		7.3E-01		1.1E-02			2.0E-04		2.1E-01		2.1E-01		
TPH (gasolines)														
TPH (middle distillates)														
TPH (residual fuels)														

TABLE F-4c. SUMMARY OF USEPA AND OTHER PUBLISHED AQUATIC HABITAT GOALS
(ug/l)

CHEMICAL PARAMETER	Freshwater							Marine					Other	
	USEPA CCC	USEPA Chronic LOEL	USEPA CMC	USEPA Acute LOEL	Ecotox Chronic Threshold (AWQC, FCV Or Tier II)	Other	Basis	USEPA CCC	USEPA Chronic LOEL	USEPA CMC	USEPA Acute LOEL	Ecotox Chronic Threshold (AWQC, FCV Or Tier II)	Value	Basis
TRICHLOROBENZENE, 1,2,4		5.0E+01		2.5E+02	1.1E+02				1.29E+02		1.6E+02			
TRICHLOROETHANE, 1,1,1				1.8E+04	6.2E+01						3.12E+04			
TRICHLOROETHANE, 1,1,2		9.4E+03		1.8E+04										
TRICHLOROETHYLENE		2.19E+04		4.5E+04	3.6E+02						2.0E+03			
TRICHLOROPHENOL, 2,4,5	6.3E+01		1.0E+02					1.1E+01		2.4E+02				
TRICHLOROPHENOL, 2,4,6		9.7E+02												
VANADIUM					1.9E+01									
VINYL CHLORIDE						7.82E+02	USDOE FW Chronic PRG							
XYLENES														
ZINC	1.2E+02		1.2E+02		1.0E+02			8.1E+01		9.0E+01		8.1E+01	1.0E+02	5% acute SW LC 50

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

References:
Primary sources USEPA (1996b); MOEE (1996); USDOE (1997). USEPA criteria summarized in A Compilation of Water Quality Goals (August 2003), CalEPA RWQCB Central Valley Region (RWQCBCV 2003 and updates).
LC 50 values for 1,4 Dioxane presented in "Solvent Stabilizers White Paper" (Mohr 2001).
Chronic goal for perchlorate from "Perchlorate Environmental Contamination (draft)" (USEPA 1998).

Notes:
Used for development of groundwater and soil screening levels.
See text for prioritization and selection of surface water quality screening levels.
Lowest Chronic Aquatic Habitat Goal: Addresses potential impact on freshwater or marine aquatic life.
Acute LOEL and CMC criteria divided by a factor of ten if selected as lowest screening level. LC 50 divided by factor of twenty.
Barium aquatic habitat goal presented in USEPA Ecotox document not considered for screening of groundwater due to low confidence in goals and elevated background concentrations of barium in Bay area groundwater.
tert Butyl Alcohol (TBA): Chronic aquatic goal based on in-house review of USEPA ECOTOX database for TBA (USEPA 2003b). Ten percent of LC0 concentration for Lepomis macrochirus (Bluegill) selected as most conservative goal of data presented.
Xylenes: Acute saltwater screening level based on review on data in UK Marine SAC summary and marine LC50 of 2.0 mg/L (Cole et al., 1999). Confidence in USDOE PRG and USEPA Ecotox goals low.
AWQC: Aquatic Water Quality Criteria
CCC: Criterion for Continuous Concentration
CMC: Criterion for Maximum Concentration
FCV: Final Chronic Value
FW: Freshwater
LOEL: Lowest Observed Effects Level
MOEE: Ontario Ministry of Environment and Energy (MOEE 1996)
PRG: USDOE Preliminary Remediation Goal for ecological concerns.
SW: Saltwater
TPH Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
USDOE: U. S. Department of Energy
USEPA: U.S. Environmental Protection Agency

TABLE F-4d. SURFACE WATER QUALITY STANDARDS FOR BIOACCUMULATION AND HUMAN CONSUMPTION OF AQUATIC ORGANISMS

(ug/l)

CHEMICAL PARAMETER	Selected Criteria	[1]California Toxics Rule	[2]USEPA NWQC
ACENAPHTHENE	2.7E+03	2.7E+03	9.9E+02
ACENAPHTHYLENE			
ACETONE			
ALDRIN	1.4E-04	1.4E-04	5.0E-05
ANTHRACENE	1.1E+05	1.1E+05	4.0E+04
ANTIMONY	4.3E+03	4.3E+03	6.4E+02
ARSENIC	1.4E-01		1.4E-01
BARIUM			
BENZENE	7.1E+01	7.1E+01	5.1E+01
BENZO(a)ANTHRACENE	4.9E-02	4.9E-02	1.8E-02
BENZO(b)FLUORANTHENE	4.9E-02	4.9E-02	1.8E-02
BENZO(k)FLUORANTHENE	4.9E-02	4.9E-02	1.8E-02
BENZO(g,h,i)PERYLENE			
BENZO(a)PYRENE	4.9E-02	4.9E-02	1.8E-02
BERYLLIUM			
BIPHENYL, 1,1-			
BIS(2-CHLOROETHYL)ETHER	1.4E+00	1.4E+00	5.3E-01
BIS(2-CHLOROISOPROPYL)ETHER	1.7E+05	1.7E+05	6.5E+04
BIS(2-ETHYLHEXYL)PHTHALATE	5.9E+00	5.9E+00	2.2E+00
BORON			
BROMODICHLOROMETHANE			
BROMOFORM	3.6E+02	3.6E+02	1.4E+02
BROMOMETHANE	4.0E+03	4.0E+03	1.5E+03
CADMIUM			
CARBON TETRACHLORIDE	4.4E+00	4.4E+00	1.6E+00
CHLORDANE	5.9E-04	5.9E-04	8.1E-04
CHLOROANILINE, p-			
CHLOROBENZENE	2.1E+04	2.1E+04	2.1E+04
CHLOROETHANE			
CHLOROFORM	4.7E+02	4.7E+02	4.7E+02
CHLOROMETHANE			
CHLOROPHENOL, 2-	4.0E+02	4.0E+02	1.5E+02
CHROMIUM (Total)			
CHROMIUM III			
CHROMIUM VI			
CHRYSENE	4.9E-02	4.9E-02	1.8E-02
COBALT			
COPPER			
CYANIDE (Free)	2.2E+05	2.2E+05	2.2E+05
DIBENZO(a,h)ANTHTRACENE	4.9E-02	4.9E-02	1.8E-02
DIBROMOCHLOROMETHANE	4.6E+01	4.6E+01	1.3E+01
1,2-DIBROMO-3-CHLOROPROPANE			
DIBROMOETHANE, 1,2-			
DICHLOROBENZENE, 1,2-	1.7E+04	1.7E+04	1.7E+04
DICHLOROBENZENE, 1,3-	2.6E+03	2.6E+03	9.6E+02
DICHLOROBENZENE, 1,4-	2.6E+03	2.6E+03	2.6E+03
DICHLOROBENZIDINE, 3,3-	7.7E-02	7.7E-02	2.8E-02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.4E-04	8.4E-04	3.1E-04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	5.9E-04	5.9E-04	2.2E-04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	5.9E-04	5.9E-04	2.2E-04
DICHLOROETHANE, 1,1-			
DICHLOROETHANE, 1,2-	9.9E+01	9.9E+01	3.7E+01
DICHLOROETHYLENE, 1,1-	3.2E+00	3.2E+00	3.2E+00

TABLE F-4d. SURFACE WATER QUALITY STANDARDS FOR BIOACCUMULATION AND HUMAN CONSUMPTION OF AQUATIC ORGANISMS
(ug/l)

CHEMICAL PARAMETER	Selected Criteria	[1]California Toxics Rule	[2]USEPA NWQC
DICHLOROETHYLENE, Cis 1,2-			
DICHLOROETHYLENE, Trans 1,2-	140000	140000	140000
DICHLOROPHENOL, 2,4-	7.9E+02	7.9E+02	2.9E+02
DICHLOROPROPANE, 1,2-	3.9E+01	3.9E+01	1.5E+01
DICHLOROPROPENE, 1,3-	1.7E+03	1.7E+03	1.7E+03
DIELDRIN	0.00014	0.00014	5.4E-05
DIETHYLPHTHALATE	120000	120000	4.4E+04
DIMETHYLPHTHALATE	2900000	2900000	1.1E+06
DIMETHYLPHENOL, 2,4-	2300	2300	8.5E+02
DINITROPHENOL, 2,4-	1.4E+04	1.4E+04	5.3E+03
DINITROTOLUENE, 2,4-	9.1E+00	9.1E+00	3.4E+00
1,4 DIOXANE			
DIOXIN (2,3,7,8-TCDD)	1.4E-08	1.4E-08	5.1E-09
ENDOSULFAN	2.4E+02	2.4E+02	8.9E+01
ENDRIN	8.1E-01	8.1E-01	8.1E-01
ETHANOL			
ETHYLBENZENE	2.9E+04	2.9E+04	2.9E+04
FLUORANTHENE	3.7E+02	3.7E+02	1.4E+02
FLUORENE	1.4E+04	1.4E+04	5.3E+03
HEPTACHLOR	2.1E-04	2.1E-04	7.9E-05
HEPTACHLOR EPOXIDE	1.1E-04	1.1E-04	3.9E-05
HEXACHLOROBENZENE	7.7E-04	7.7E-04	2.9E-04
HEXACHLOROBUTADIENE	5.0E+01	5.0E+01	1.8E+01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	6.3E-02	6.3E-02	6.3E-02
HEXACHLOROETHANE	8.9E+00	8.9E+00	3.3E+00
INDENO(1,2,3-cd)PYRENE	4.9E-02	4.9E-02	1.8E-02
LEAD			
MERCURY	5.1E-02	5.1E-02	3.0E-01
METHOXYCHLOR			
METHYLENE CHLORIDE	1.6E+03	1.6E+03	5.9E+02
METHYL ETHYL KETONE			
METHYL ISOBUTYL KETONE			
METHYL MERCURY			
METHYLNAPHTHALENE (total 1- & 2-)			
METHYL TERT BUTYL ETHER			
MOLYBDENUM			
NAPHTHALENE			
NICKEL	4.6E+03	4.6E+03	4.6E+03
PENTACHLOROPHENOL	8.2E+00	8.2E+00	3.0E+00
PERCHLORATE			
PHENANTHRENE			
PHENOL	4.6E+06	4.6E+06	1.7E+06
POLYCHLORINATED BIPHENYLS (PCBs)	1.7E-04	1.7E-04	6.4E-05
PYRENE	1.1E+04	1.1E+04	4.0E+03
SELENIUM			
SILVER			
STYRENE			
tert-BUTYL ALCOHOL			
TETRACHLOROETHANE, 1,1,1,2-			
TETRACHLOROETHANE, 1,1,2,2-	1.1E+01	1.1E+01	4.0E+00
TETRACHLOROETHYLENE	8.9E+00	8.85E+00	3.3E+00
THALLIUM	6.3E+00	6.3E+00	6.3E+00
TOLUENE	2.0E+05	2.0E+05	2.0E+05

TABLE F-4d. SURFACE WATER QUALITY STANDARDS FOR
BIOACCUMULATION AND HUMAN CONSUMPTION
OF AQUATIC ORGANISMS
(ug/l)

CHEMICAL PARAMETER	Selected Criteria	[1]California Toxics Rule	[2]USEPA NWQC
TOXAPHENE	7.5E-04	7.5E-04	2.8E-04
TPH (gasolines)			
TPH (middle distillates)			
TPH (residual fuels)			
TRICHLOROBENZENE, 1,2,4-			
TRICHLOROETHANE, 1,1,1-			
TRICHLOROETHANE, 1,1,2-	4.2E+01	4.2E+01	1.6E+01
TRICHLOROETHYLENE	8.1E+01	8.1E+01	3.0E+01
TRICHLOROPHENOL, 2,4,5-	3.6E+03		3.6E+03
TRICHLOROPHENOL, 2,4,6-	6.5E+00	6.5E+00	
VANADIUM			
VINYL CHLORIDE	5.3E+02	5.25E+02	5.30E+02
XYLENES			
ZINC			

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

References:

1. 40 CFR Part 131: Water Quality Standards; Establishment of Numerical Criteria for Priority
   Toxic Pollutants for the State of California: Federal Register, May 18, 2000.
2. USEPA National Recommended Water Quality Criteria: 2002, EPA-822-R-02-047.

Notes:

California CTR goals considered for surface water (see Tables F-2 series) if available.

Addresses potential accumulation of chemical in aquatic organisms and subsequent
consumption by humans.

TABLE F-5. AGRICULTURAL
WATER QUALITY GOALS
(ug/l)

CHEMICAL PARAMETER	Agricultural Water Quality Goals
ACENAPHTHENE	-
ACENAPHTHYLENE	-
ACETONE	-
ALDRIN	-
ANTHRACENE	-
ANTIMONY	-
ARSENIC	1.0E+02
BARIUM	-
BENZENE	-
BENZO(a)ANTHRACENE	-
BENZO(b)FLUORANTHENE	-
BENZO(k)FLUORANTHENE	-
BENZO(g,h,i)PERYLENE	-
BENZO(a)PYRENE	-
BERYLLIUM	1.0E+02
BIPHENYL, 1,1-	-
BIS(2-CHLOROETHYL)ETHER	-
BIS(2-CHLOROISOPROPYL)ETHER	-
BIS(2-ETHYLHEXYL)PHTHALATE	-
BORON	7.0E+02
BROMODICHLOROMETHANE	-
BROMOFORM	-
BROMOMETHANE	-
CADMIUM	1.0E+01
CARBON TETRACHLORIDE	-
CHLORDANE	-
CHLOROANILINE, p-	-
CHLOROBENZENE	-
CHLOROETHANE	-
CHLOROFORM	-
CHLOROMETHANE	-
CHLOROPHENOL, 2-	-
CHROMIUM (Total)	-
CHROMIUM III	-
CHROMIUM VI	1.0E+02
CHRYSENE	-
COBALT	5.0E+01
COPPER	2.0E+02
CYANIDE (Free)	-
DIBENZO(a,h)ANTHRACENE	-
DIBROMOCHLOROMETHANE	-
1,2-DIBROMO-3-CHLOROPROPANE	-
DIBROMOETHANE, 1,2-	-
DICHLOROBENZENE, 1,2-	-
DICHLOROBENZENE, 1,3-	-
DICHLOROBENZENE, 1,4-	-
DICHLOROBENZIDINE, 3,3-	-
DICHLORODIPHENYLDICHLOROETHANE (DDD)	-
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	-
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	-
DICHLOROETHANE, 1,1-	-
DICHLOROETHANE, 1,2-	-
DICHLOROETHYLENE, 1,1-	-
DICHLOROETHYLENE, Cis 1,2-	-

TABLE F-5. AGRICULTURAL
WATER QUALITY GOALS
(ug/l)

CHEMICAL PARAMETER	Agricultural Water Quality Goals
DICHLOROETHYLENE, Trans 1,2-	-
DICHLOROPHENOL, 2,4-	-
DICHLOROPROPANE, 1,2-	-
DICHLOROPROPENE, 1,3-	-
DIELDRIN	-
DIETHYLPHTHALATE	-
DIMETHYLPHTHALATE	-
DIMETHYLPHENOL, 2,4-	-
DINITROPHENOL, 2,4-	-
DINITROTOLUENE, 2,4-	-
1,4 DIOXANE	-
DIOXIN (2,3,7,8-TCDD)	-
ENDOSULFAN	-
ENDRIN	-
ETHANOL	-
ETHYLBENZENE	-
FLUORANTHENE	-
FLUORENE	-
HEPTACHLOR	-
HEPTACHLOR EPOXIDE	-
HEXACHLOROBENZENE	-
HEXACHLOROBUTADIENE	-
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	-
HEXACHLOROETHANE	-
INDENO(1,2,3-cd)PYRENE	-
LEAD	-
MERCURY	-
METHOXYCHLOR	-
METHYLENE CHLORIDE	-
METHYL ETHYL KETONE	-
METHYL ISOBUTYL KETONE	-
METHYL MERCURY	-
METHYLNAPHTHALENE (total 1- & 2-)	-
METHYL TERT BUTYL ETHER	-
MOLYBDENUM	1.0E+01
NAPHTHALENE	-
NICKEL	2.0E+02
PENTACHLOROPHENOL	-
PERCHLORATE	-
PHENANTHRENE	-
PHENOL	-
POLYCHLORINATED BIPHENYLS (PCBs)	-
PYRENE	-
SELENIUM	2.0E+01
SILVER	-
STYRENE	-
tert-BUTYL ALCOHOL	-
TETRACHLOROETHANE, 1,1,1,2-	-
TETRACHLOROETHANE, 1,1,2,2-	-
TETRACHLOROETHYLENE	-
THALLIUM	-
TOLUENE	-
TOXAPHENE	-

TABLE F-5. AGRICULTURAL
WATER QUALITY GOALS
(ug/l)

CHEMICAL PARAMETER	Agricultural Water Quality Goals
TPH (gasolines)	-
TPH (middle distillates)	-
TPH (residual fuels)	-
TRICHLOROBENZENE, 1,2,4-	-
TRICHLOROETHANE, 1,1,1-	-
TRICHLOROETHANE, 1,1,2-	-
TRICHLOROETHYLENE	-
TRICHLOROPHENOL, 2,4,5-	-
TRICHLOROPHENOL, 2,4,6-	-
VANADIUM	1.0E+02
VINYL CHLORIDE	-
XYLENES	-
ZINC	2.0E+03

Red: >25% change in comparison to July 2003 ESL.

References:

A Compiliation of Water Quality Goals (RWQCBCV 2003).

Notes:

Addresses use of water (including groundwater) for agricultural/irrigation purposes.

TABLE F-6. USEPA REGION IX
TAP WATER GOALS
(ug/l)

CHEMICAL PARAMETER	Tap Water Goal (NonCarcinogenic Effects)	Tap Water Goal (Carcinogenic Effects)
ACENAPHTHENE	3.7E+02	
ACENAPHTHYLENE	2.4E+02	
ACETONE	5.5E+03	
ALDRIN	1.1E+00	4.0E-03
ANTHRACENE	1.8E+03	
ANTIMONY	1.5E+01	
ARSENIC	1.1E+01	7.1E-03
BARIUM	2.6E+03	
BENZENE	5.8E+01	1.1E-01
BENZO(a)ANTHRACENE		5.6E-02
BENZO(b)FLUORANTHENE		5.6E-02
BENZO(k)FLUORANTHENE		5.6E-02
BENZO(g,h,i)PERYLENE	1.5E+03	
BENZO(a)PYRENE		5.6E-03
BERYLLIUM	7.3E+01	
BIPHENYL, 1,1-	3.0E+02	
BIS(2-CHLOROETHYL)ETHER		4.5E-03
BIS(2-CHLOROISOPROPYL)ETHER	2.4E+02	2.7E-01
BIS(2-ETHYLHEXYL)PHTHALATE	7.3E+02	2.2E+01
BORON	7.3E+03	
BROMODICHLOROMETHANE	1.2E+02	8.6E-02
BROMOFORM	7.3E+02	8.5E+00
BROMOMETHANE	8.5E+00	
CADMIUM	1.8E+01	1.8E-01
CARBON TETRACHLORIDE	2.0E+01	7.5E-02
CHLORDANE	1.8E+01	5.2E-02
CHLOROANILINE, p-	1.5E+02	
CHLOROBENZENE	1.1E+02	
CHLOROETHANE	8.6E+03	3.9E+00
CHLOROFORM	8.0E+01	5.3E-01
CHLOROMETHANE	6.3E+02	4.3E-01
CHLOROPHENOL, 2-	3.0E+01	
CHROMIUM (Total)		
CHROMIUM III	5.5E+04	
CHROMIUM VI	1.1E+02	
CHRYSENE		5.6E-01
COBALT	7.3E+02	
COPPER	1.5E+03	
CYANIDE (Free)	7.3E+02	
DIBENZO(a,h)ANTHTRACENE		1.6E-02
DIBROMOCHLOROMETHANE	1.2E+02	1.2E-01
1,2-DIBROMO-3-CHLOROPROPANE	3.5E-01	1.6E-03
DIBROMOETHANE, 1,2-	1.8E+01	1.4E-02
DICHLOROBENZENE, 1,2-	3.7E+02	
DICHLOROBENZENE, 1,3-	1.8E+02	
DICHLOROBENZENE, 1,4-	6.6E+02	3.3E-01
DICHLOROBENZIDINE, 3,3-		5.6E-02
DICHLORODIPHENYLDICHLOROETHANE (DDD)		2.8E-01
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)		2.0E-01
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.8E+01	2.0E-01
DICHLOROETHANE, 1,1-	8.0E+02	2.0E+00
DICHLOROETHANE, 1,2-	1.0E+01	1.6E-01
DICHLOROETHYLENE, 1,1-	3.4E+02	
DICHLOROETHYLENE, Cis 1,2-	6.1E+01	

TABLE F-6. USEPA REGION IX
TAP WATER GOALS
(ug/l)

CHEMICAL PARAMETER	Tap Water Goal (NonCarcinogenic Effects)	Tap Water Goal (Carcinogenic Effects)
DICHLOROETHYLENE, Trans 1,2-	1.2E+02	
DICHLOROPHENOL, 2,4-	1.1E+02	
DICHLOROPROPANE, 1,2-	6.7E+00	3.1E-01
DICHLOROPROPENE, 1,3-	1.2E+02	1.8E-01
DIELDRIN	1.8E+00	4.2E-03
DIETHYLPHTHALATE	2.9E+04	
DIMETHYLPHTHALATE	3.7E+05	
DIMETHYLPHENOL, 2,4-	1.2E+02	
DINITROPHENOL, 2,4-	7.3E+01	
DINITROTOLUENE, 2,4-	7.3E+01	2.2E-01
1,4 DIOXANE		2.5E+00
DIOXIN (2,3,7,8-TCDD)		5.2E-07
ENDOSULFAN	2.2E+02	
ENDRIN	1.1E+01	
ETHANOL		
ETHYLBENZENE	1.9E+03	
FLUORANTHENE	1.5E+03	
FLUORENE	2.4E+02	
HEPTACHLOR	1.8E+01	1.6E-02
HEPTACHLOR EPOXIDE	4.7E-01	1.2E-02
HEXACHLOROBENZENE	2.9E+01	3.7E-02
HEXACHLOROBUTADIENE	1.1E+01	8.6E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	1.1E+01	6.1E-02
HEXACHLOROETHANE	3.7E+01	1.7E+00
INDENO(1,2,3-cd)PYRENE		5.6E-02
LEAD		
MERCURY	1.1E+01	
METHOXYCHLOR	1.8E+02	
METHYLENE CHLORIDE	1.6E+03	2.1E+00
METHYL ETHYL KETONE	1.9E+03	
METHYL ISOBUTYL KETONE	1.6E+02	
METHYL MERCURY	3.7E+00	
METHYLNAPHTHALENE (total 1- & 2-)	2.4E+02	
METHYL TERT BUTYL ETHER	1.1E+04	1.1E+01
MOLYBDENUM	1.8E+02	
NAPHTHALENE	1.8E+01	9.3E-02
NICKEL	7.3E+02	
PENTACHLOROPHENOL	1.1E+03	8.3E-01
PERCHLORATE	3.7E+00	
PHENANTHRENE	2.4E+02	
PHENOL	1.1E+04	
POLYCHLORINATED BIPHENYLS (PCBs)	7.3E-01	3.4E-02
PYRENE	1.8E+02	
SELENIUM	1.8E+02	
SILVER	1.8E+02	
STYRENE	1.6E+03	
tert-BUTYL ALCOHOL		3.4E+00
TETRACHLOROETHANE, 1,1,1,2-	1.8E+02	4.3E-01
TETRACHLOROETHANE, 1,1,2,2-	3.7E+02	5.3E-02
TETRACHLOROETHYLENE	. 6.1E+01	1.0E-01
THALLIUM	2.4E+00	
TOLUENE	5.8E+02	
TOXAPHENE		5.6E-02

TABLE F-6. USEPA REGION IX
TAP WATER GOALS
(ug/l)

CHEMICAL PARAMETER	Tap Water Goal (NonCarcinogenic Effects)	Tap Water Goal (Carcinogenic Effects)
TPH (gasolines)	9.3E+01	
TPH (middle distillates)	9.3E+01	
TPH (residual fuels)	1.1E+03	
TRICHLOROBENZENE, 1,2,4-	7.2E+00	1.9E+01
TRICHLOROETHANE, 1,1,1-	3.2E+03	
TRICHLOROETHANE, 1,1,2-	2.4E+01	1.9E-01
TRICHLOROETHYLENE	1.1E+01	1.4E+00
TRICHLOROPHENOL, 2,4,5-	6.1E+02	
TRICHLOROPHENOL, 2,4,6-		9.6E-01
VANADIUM	2.6E+02	
VINYL CHLORIDE	7.2E+01	4.2E-02
XYLENES	1.2E+03	
ZINC	1.1E+04	

Red: >25% change in comparison to July 2003 ESL.

References:

Calculated using Tap Water equations in USEPA Region IX Preliminary Remediation Goals document (USEPA 2004).

Notes:

Addresses use of water for drinking water and inhalation of volatile chemicals during showering.

Tap Water value for TBA calculated using PRG methodology (not in PRGs).

Target risk = 10-6. Target HQ = 1.0. Adjusted to CalEPA CSFs. See Appendix 2 for equations.

TABLE G. SOIL SCREENING LEVELS FOR LEACHING CONCERNS

CHEMICAL	Organic Carbon Coefficient (Koc) (cm³/g)	Henry's Law Constant (H) (atm-m³/mol)	Dilution/Atenuation Factor (DAF)	Saturation Limit (mg/kg)	Target Groundwater Concentration (Drinking Water Resource) (Table F-1a) (ug/L)	Target Groundwater Concentration (NON-Drinking Water Resource) (Table F-1b) (ug/L)	Soil Leaching Screening Level (Drinking Water Resource) (mg/kg)	Soil Leaching Screening Level (NON-Drinking Water Resource) (mg/kg)
ACENAPHTHENE	4.90E+03	1.55E-04	8.14E+02	1.3E+02	2.0E+01	2.3E+01	1.6E+01	1.9E+01
ACENAPHTHYLENE	2.50E+03	1.45E-03	4.24E+02	5.9E+01	3.0E+01	3.0E+01	1.3E+01	1.3E+01
ACETONE	5.75E-01	3.88E-05	3.36E-01	1.0E+05	1.5E+03	1.5E+03	5.0E-01	5.0E-01
#ALDRIN	4.90E+04	4.96E-05	8.13E-03	5.0E+00	2.0E-03	1.3E-01	5.0E+00	5.0E+00
ANTHRACENE	2.35E+04	6.50E-05	3.90E+03	6.1E+00	7.3E-01	7.3E-01	2.8E+00	2.8E+00
ANTIMONY					6.0E+00	3.0E+01		
ARSENIC					3.6E+01	3.6E+01		
BARIUM					1.0E+03	1.0E+03		
BENZENE	5.90E+01	5.56E-03	4.43E+01	8.7E+02	1.0E+00	4.6E+01	4.4E-02	2.0E+00
#BENZO(a)ANTHRACENE	2.00E+05	1.00E-06	3.32E+04	1.2E+01	2.7E-02	2.7E-02	1.2E+01	1.2E+01
#BENZO(b)FLUORANTHENE	5.50E+05	1.22E-05	9.13E+04	4.6E+01	2.9E-02	2.9E-02	4.6E+01	4.6E+01
#BENZO(k)FLUORANTHENE	5.50E+05	3.87E-05	9.13E+04	2.6E+00	2.9E-02	4.0E-01	2.7E+00	3.7E+01
#BENZO(g,h,i)PERYLENE	1.60E+06	1.44E-07	2.66E+05	2.5E+00	1.0E-01	1.0E-01	2.7E+01	2.7E+01
#BENZO(a)PYRENE	5.50E+06	4.90E-07	9.13E+05	1.3E-02	1.4E-02	1.4E-02	1.3E+02	1.3E+02
BERYLLIUM					2.7E+00	2.7E+00		
BIPHENYL, 1,1-	7.76E+03	3.00E-04	1.29E+03	3.5E-02	5.0E+00	5.0E+00	6.5E-01	6.5E+00
BIS(2-CHLOROETHYL)ETHER	7.60E+01	1.80E-05	1.27E+01	9.6E-03	1.4E-02	6.1E-01	1.8E-04	7.8E-01
BIS(2-CHLOROISOPROPYL)ETHER	6.10E+01	1.13E-04	1.08E+01	7.9E-02	5.0E-01	6.1E+01	5.4E-03	6.6E-01
BIS(2-ETHYLHEXYL)PHTHALATE	1.00E+05	3.00E-07	1.66E+04	7.8E-02	4.0E+00	3.2E+01	6.6E+01	5.3E+02
BORON					1.6E+00	1.6E+00		
BROMODICHLOROMETHANE	5.50E+01	1.60E-03	1.91E+01	3.0E-03	1.0E+02	1.7E+02	1.9E+00	3.2E+00
BROMOFORM	1.10E+02	5.32E-04	2.16E+01	2.4E-03	1.0E+02	3.2E+02	2.2E+00	6.9E+01
BROMOMETHANE	9.00E+00	6.24E-03	4.02E+01	3.1E-03	9.8E+00	1.6E+02	3.9E-01	6.4E+00
CADMIUM					1.1E+00	1.1E+00		
CARBON TETRACHLORIDE	1.74E+02	3.04E-02	2.18E+02	1.1E-03	5.0E-01	9.3E+00	1.1E-01	2.0E+00
#CHLORDANE	4.40E+04	4.79E-05	7.30E+03	1.5E-01	4.0E-03	4.0E-03	1.5E+01	1.5E+01
CHLOROANILINE, p-	6.40E+01	3.31E-07	1.06E+01	1.3E-03	5.0E+00	5.0E+00	5.3E-02	5.3E-02
CHLOROBENZENE	2.19E+02	3.70E-03	5.93E+01	6.8E-02	2.5E+01	2.5E+01	1.5E+00	1.5E+00
CHLOROETHANE	1.47E+01	1.10E-02	7.07E+01	1.6E-03	1.2E+01	1.2E+01	8.5E-01	8.5E-01
CHLOROFORM	3.98E+01	3.67E-03	2.94E+01	2.9E-03	7.0E+01	3.3E+02	2.1E+00	9.8E+00
CHLOROMETHANE	3.50E+01	2.40E-02	1.55E+02	4.1E-03	1.3E+00	4.1E+01	2.1E-01	6.4E+00
CHLOROPHENOL, 2-	3.98E+02	3.91E-04	6.85E+01	5.5E-04	1.8E-01	1.8E+00	1.2E-02	1.2E-01
CHROMIUM (Total)					5.0E+01	5.0E+01		
CHROMIUM III					1.8E+02	1.8E+02		
CHROMIUM VI					1.1E+01	1.1E+01		
#CHRYSENE	4.00E+05	9.46E-05	6.64E+04	3.8E+00	2.9E-01	3.5E-01	1.9E+01	2.3E+01
COBALT					3.0E+00	3.0E+00		
COPPER					3.1E+00	3.1E+00		
CYANIDE (Free)	1.70E+01	1.30E-04	3.63E+00	2.0E-05	1.0E+00	1.0E+00	3.6E-03	3.6E-03
#DIBENZO(a,h)ANTHTRACENE	3.30E+06	7.30E-08	5.48E+05	9.9E+00	8.5E-03	2.5E-01	9.9E+00	1.4E+02

TABLE G. SOIL SCREENING LEVELS FOR LEACHING CONCERNS

CHEMICAL	Organic Carbon Coefficient (Koc) (cm³/g)	Henry's Law Constant (H) (atm-m³/mol)	Dilution/ Attenuation Factor (DAF)	Saturation Limit (mg/kg)	Target Groundwater Concentration (Drinking Water Resource) (Table F-1a) (ug/L)	Target Groundwater Concentration (NON-Drinking Water Resource) (Table F-1b) (ug/L)	Soil Leaching Screening Level (Drinking Water Resource) (mg/kg)	Soil Leaching Screening Level (NON-Drinking Water Resource) (mg/kg)
DIBROMOCHLOROMETHANE	4.68E+02	8.50E-04	8.30E+01	1.3E+04	1.0E+02	1.7E+02	8.3E+00	1.4E+01
1,2-DIBROMO-3-CHLOROPROPANE	1.30E-02	1.47E-04	2.25E+01	1.1E+03	2.0E-01	2.0E-01	4.5E-03	4.5E-03
DIBROMOETHANE, 1,2-	2.81E-01	3.20E-04	6.65E+00	9.2E+02	5.0E-02	1.5E+02	3.3E-04	1.0E+00
DICHLOROBENZENE, 1,2-	6.17E+02	1.90E-03	1.14E+02	6.0E+02	1.0E+01	1.4E+01	1.1E+00	1.6E+00
DICHLOROBENZENE, 1,3-	6.17E+02	1.90E-03	1.14E+02	6.0E+02	6.5E+01	6.5E+01	7.4E+00	7.4E+00
DICHLOROBENZENE, 1,4-	6.17E+02	2.43E-03	1.18E+02	2.8E+02	5.0E+00	1.5E+01	5.9E-01	1.8E+00
DICHLOROBENZIDINE, 3,3-	1.60E+03	8.33E-07	2.66E+02	3.0E+01	2.9E-02	2.5E+02	7.7E-03	6.6E+01
#DICHLORODIPHENYLDICHLOROETHANE (DDD)	7.80E+05	7.96E-06	1.29E+05	7.5E+02	1.0E-03	1.0E-03	7.5E+02	7.5E+02
#DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	4.40E+06	6.80E-05	7.30E+05	1.1E+03	1.0E-03	1.0E-03	1.1E+03	1.1E+03
#DICHLORODIPHENYLTRICHLOROETHANE (DDT)	2.40E+05	3.89E-05	3.98E+04	4.3E+00	1.0E-03	1.0E-03	4.3E+00	4.3E+00
DICHLOROETHANE, 1,1-	3.16E+01	5.62E-03	4.01E+01	1.7E+03	5.0E+00	4.7E+01	2.0E-01	1.9E+00
DICHLOROETHANE, 1,2-	1.74E+01	9.79E-04	8.97E+00	1.8E+03	5.0E-01	2.0E+02	4.5E-03	1.8E+00
DICHLOROETHYLENE, 1,1-	5.89E+01	2.61E-02	1.72E+02	1.5E+03	6.0E+00	2.5E+01	1.0E+00	4.3E+00
DICHLOROETHYLENE, Cis 1,2-	3.55E+01	4.08E-03	3.12E+01	1.2E+03	6.0E+00	5.9E+02	1.9E-01	1.8E+01
DICHLOROETHYLENE, Trans 1,2-	5.25E+01	9.38E-03	6.69E+01	3.1E+03	1.0E+01	5.9E+02	6.7E-01	3.9E+01
DICHLOROPHENOL, 2,4-	6.00E+03	2.80E-06	9.96E+02	1.6E+05	3.0E-01	3.0E+00	3.0E-01	3.0E+00
DICHLOROPROPANE, 1,2-	4.37E+01	2.80E-03	2.46E+01	1.1E+03	5.0E+00	1.0E+02	1.2E-01	2.5E+00
DICHLOROPROPENE, 1,3-	4.57E+01	1.77E-02	1.17E+02	1.4E+03	5.0E-01	5.3E+01	5.9E-02	6.2E+00
DIELDRIN	7.40E+03	5.84E-05	1.23E+03	8.3E+00	1.9E-03	1.9E-03	2.3E-03	2.3E-03
DIETHYLPHTHALATE	1.40E+02	1.14E-06	2.32E+01	8.4E+02	1.5E+00	1.5E+00	3.5E-02	3.5E-02
DIMETHYLPHTHALATE	1.40E+02	1.05E-07	2.32E+01	4.7E+03	1.5E+00	1.5E+00	3.5E-02	3.5E-02
DIMETHYLPHENOL, 2,4-	4.00E+01	1.70E-05	6.75E+00	2.7E+03	1.0E+02	1.1E+02	6.7E-01	7.4E-01
DINITROPHENOL, 2,4-	1.70E+01	6.45E-10	2.82E+00	1.1E+03	1.4E+01	7.5E+01	4.0E-02	2.1E-01
DINITROTOLUENE, 2,4-	4.50E+01	4.50E-06	7.50E+00	1.0E+02	1.1E-01	1.2E+02	8.5E-04	8.6E-01
1,4 DIOXANE	3.50E+00	3.00E-06	6.00E-01	1.2E+05	3.0E+00	5.0E+04	1.8E-03	3.0E+01
DIOXIN (2,3,7,8-TCDD)					5.0E-06	5.0E-06		
ENDOSULFAN	3.20E+03	1.00E-05	5.31E+02	2.9E+00	8.7E-03	8.7E-03	4.6E-03	4.6E-03
ENDRIN	1.70E+03	7.51E-06	2.82E+02	2.7E+00	2.3E-03	2.3E-03	6.5E-04	6.5E-04
ETHANOL	3.09E-01	6.29E-06	9.03E+00	1.0E+05	5.0E+04	5.0E+04	4.5E-01	4.5E+01
ETHYLBENZENE	3.63E+02	7.88E-03	1.09E+02	4.0E+02	3.0E+01	2.9E+02	3.3E+00	3.2E+01
#FLUORANTHENE	3.80E+04	6.50E-06	6.31E+03	6.0E+01	8.0E+00	8.0E+00	6.0E+01	6.0E+01
FLUORENE	1.38E+04	7.70E-05	2.29E+03	1.6E+02	3.9E+00	3.9E+00	8.9E+00	8.9E+00
HEPTACHLOR	2.20E+04	1.48E-03	3.66E+03	7.4E+00	3.8E-03	3.8E-03	1.4E-02	1.4E-02
HEPTACHLOR EPOXIDE	2.30E+04	3.16E-05	3.82E+03	4.8E+01	3.8E-03	3.8E-03	1.5E-02	1.5E-02
#HEXACHLOROBENZENE	1.20E+06	1.70E-03	1.99E+05	7.9E+02	1.0E+00	3.7E+00	7.9E+02	7.9E+02
HEXACHLOROBUTADIENE	2.90E+04	2.56E-02	4.97E+03	3.5E+02	2.1E-01	4.7E+00	1.0E+00	2.3E+01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	3.70E+03	4.93E-07	6.14E+02	1.6E+02	8.0E-02	8.0E-02	4.9E-02	4.9E-02
HEXACHLOROETHANE	2.00E+04	9.85E-03	3.38E+03	6.0E+03	7.0E-01	1.2E+01	2.4E+00	4.1E+01
#INDENO(1,2,3-cd)PYRENE	1.60E+06	6.95E-08	2.66E+05	5.1E+00	2.9E-02	2.9E-02	7.7E+00	7.7E+00
LEAD					2.5E+00	2.5E+00		

TABLE G. SOIL SCREENING LEVELS FOR LEACHING CONCERNS

CHEMICAL	Organic Carbon Coefficient (Koc) (cm³/g)	Henry's Law Constant (H) (atm-m³/mol)	Dilution/Attenuation Factor (DAF)	Saturation Limit (mg/kg)	Target Groundwater Concentration (Drinking Water Resource) (Table F-1a) (ug/L)	Target Groundwater Concentration (NON-Drinking Water Resource) (Table F-1b) (ug/L)	Soil Leaching Screening Level (Drinking Water Resource) (mg/kg)	Soil Leaching Screening Level (NON-Drinking Water Resource) (mg/kg)
MERCURY					1.2E-02	1.2E-02		
#METHOXYCHLOR	7.90E+04	1.58E-05	1.31E+04	1.9E+01	1.9E-02	1.9E-02	1.9E+01	1.9E+01
METHYLENE CHLORIDE	1.11E+01	2.19E-03	1.54E+01	2.4E+03	5.0E+00	2.2E+03	7.7E-02	3.4E-02
METHYL ETHYL KETONE	4.50E+00	2.74E-05	9.17E-01	3.4E+04	4.2E-03	1.4E+04	3.9E+00	1.3E+01
METHYL ISOBUTYL KETONE	1.34E+02	1.40E-04	2.31E+01	1.7E+04	1.2E-02	1.7E+02	2.8E+00	3.9E+00
METHYL MERCURY					3.0E-03	3.0E-03		
METHYLNAPHTHALENE (total 1- & 2-)	7.20E+02	2.90E-04	1.21E+02	1.1E+02	2.1E+00	2.1E+00	2.5E-01	2.5E-01
METHYL TERT BUTYL ETHER	6.00E+00	5.87E-04	4.64E+00	2.1E+04	5.0E+00	1.8E+03	2.3E-02	8.4E+00
MOLYBDENUM					3.5E-01	2.4E+02		
NAPHTHALENE	1.19E+03	4.83E-04	2.01E+02	2.2E+02	1.7E-01	2.4E+01	3.4E+00	4.8E+00
NICKEL					8.2E+00	8.2E+00		
PENTACHLOROPHENOL	3.20E+04	2.80E-06	5.31E+03	>1000000	1.0E+00	7.9E+00	5.3E+00	4.2E+01
PERCHLORATE					6.0E+00	6.0E+02	1.0E-02	1.2E+00
PHENANTHRENE	1.40E+04	3.93E-05	2.32E+03	6.9E+01	4.6E+00	4.6E+00	1.1E+01	1.1E+01
PHENOL	9.10E+01	1.30E-06	1.51E+01	5.2E+04	5.0E+00	1.3E+03	7.6E-02	1.9E+01
#POLYCHLORINATED BIPHENYLS (PCBs)	3.30E+04	5.20E-04	5.48E+03	6.3E+00	1.4E-02	1.4E-02	6.3E+00	6.3E+00
#PYRENE	1.05E+05	1.10E-05	1.74E+04	8.5E+01	2.0E+00	2.0E+00	8.5E+01	8.5E+01
SELENIUM					5.0E+00	5.0E+00		
SILVER					1.9E-01	1.9E-01		
STYRENE	7.76E+02	2.75E-03	1.46E+02	1.5E+03	1.0E+01	1.0E+02	1.5E+00	1.5E+01
tert-BUTYL ALCOHOL	3.70E+01	1.17E-05	6.21E+00	3.2E+05	1.2E+01	1.8E+04	7.3E-02	1.1E+02
TETRACHLOROETHANE, 1,1,1,2-	9.37E+01	3.45E-04	1.77E+01	2.0E+03	1.3E+00	9.3E+02	2.4E-02	1.6E+01
TETRACHLOROETHANE, 1,1,2,2-	9.37E+01	3.45E-04	1.77E+01	2.0E+03	1.0E+00	1.9E+02	1.8E-02	3.4E+00
TETRACHLOROETHYLENE	1.55E+02	1.84E-02	1.40E+02	2.3E+02	5.0E+00	1.2E+02	7.0E-01	1.7E+01
THALLIUM					2.0E+00	2.0E+01		
TOLUENE	1.82E+02	6.64E-03	7.14E+01	6.5E+02	4.0E+01	1.3E+02	2.9E+00	9.3E+00
TOXAPHENE	4.90E+03	2.10E-01	2.12E+03	9.3E+01	2.0E-04	2.0E-04	4.2E-04	4.2E-04
TPH (gasolines)	5.00E+03	7.20E-04	8.34E+02	4.5E+03	1.0E+02	5.0E+02	1.0E+02	4.0E+02
TPH (middle distillates)	5.00E+03	7.20E-04	8.34E+02	1.5E+02	1.0E+02	6.4E+02	5.0E+02	5.0E+02
TPH (residual fuels)					1.0E+02	6.4E+02	1.0E+03	1.0E+03
TRICHLOROBENZENE, 1,2,4-	1.78E+03	1.42E-03	3.04E+02	3.2E+03	2.5E-01	2.5E+01	7.6E+00	7.6E+00
TRICHLOROETHANE, 1,1,1-	1.10E+02	1.72E-02	1.25E+02	1.2E+03	6.2E+01	6.2E+01	7.8E+00	7.8E+00
TRICHLOROETHANE, 1,1,2-	5.01E+01	9.13E-04	1.40E+01	1.8E+03	5.0E+00	3.5E+02	7.0E-02	4.8E+00
TRICHLOROETHYLENE	1.66E+02	1.03E-02	9.15E+01	1.3E+03	5.0E+00	3.6E+01	4.6E-01	3.3E+01
TRICHLOROPHENOL, 2,4,5-	8.90E+01	2.18E-04	1.61E+01	7.6E+02	1.1E+01	1.1E+01	1.8E-01	1.8E-01
TRICHLOROPHENOL, 2,4,6-	2.00E+03	4.00E-06	3.32E+02	9.7E+03	5.0E-01	4.9E+02	1.7E-01	1.6E+02
VANADIUM					1.5E-01	1.9E+01		
VINYL CHLORIDE	1.86E+01	2.70E-02	1.71E+02	1.2E+03	5.0E-01	3.8E+00	8.5E-02	6.6E-01
XYLENES	4.07E+02	7.34E-03	1.13E+02	4.2E+02	2.0E+01	1.0E+02	2.3E+00	1.1E+01
ZINC					8.1E+01	8.1E+01		

Table G (Soil Leaching)

TABLE G. SOIL SCREENING LEVELS FOR LEACHING CONCERNS

					Target Groundwater Concentrations		Soil Leaching Screening Levels	
	Organic Carbon Coefficient (Koc)	Henry's Law Constant (H)	Dilution/Atenuation Factor (DAF)	Saturation Limit	Target Groundwater Concentration (Drinking Water Resource) (Table F-1a)	Target Groundwater Concentration (NON-Drinking Water Resource) (Table F-1b)	Soil Leaching Screening Level (Drinking Water Resource)	Soil Leaching Screening Level (NON-Drinking Water Resource)
CHEMICAL	(cm³/g)	(atm-m³/mol)		(mg/kg)	(ug/L)	(ug/L)	(mg/kg)	(mg/kg)

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Notes:

Soil leaching equation from Ontario MOEE guidance (see text).

Groundwater Category Drinking Water Resource - protective of groundwater that is a source of drinking water AND protective of discharge of groundwater to a surface water and subsequent impact on aquatic life.

Groundwater Category NON-Drinking Water Resource - protective of discharge of impacted groundwater to surface water and subsequent impact on aquatic life.

#: Leaching model used considered to be excessively conservative for highly sorptive chemicals. For chemicals with koc values greater than 30,000 cm³/g, theoretical soil saturation level ("sat") used in place of leaching model screening level if higher (see text). Soil saturation levels calculated using equation presented in USEPA Region IX PRG guidance (USEPA 2004, see Appendix 2). Exceptions include bis(2-ethylhexyl)phthalate and pentachlorophenol (see text).

TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

Physio-Chemical constants for chemicals from USEPA Region IX (USEPA 2004) or Ontario MOEE (MOEE 1996) when not available unless otherwise noted (see also Table J).

Physio-Chemical constants for TPH (gasolines and middle distillates) based on constants developed for C11 to C22 aromatic carbon range fraction by Massachusetts DEP and used to develop RBSLs for leaching of TPH in general from soil (MADEP 1997). Soil leaching level rounded to nearest hundred.

Target groundwater concentrations from Table F-1a and F-1b.

Ethanol Dilution/Attenuation Factor (DAF) modified by a factor of ten to take into account anticipated high biodegradation rate in nature (refer to Section 3.4 and Chapter 5 of Appendix 1).

Target groundwater concentration and corresponding soil leaching levels for TPH based on criteria in Board Order 99-045 for San Francisco Airport (RWQCBSF,1999).

Screening Levels for TPH (gasolines) and TPH (middle distillates) rounded to nearest 100 mg/kg.

TPH (residual fuels) soil screening level for leaching from California Regional Water Board, Region 4 - drinking water protection, C23-C32 carbon range (RWQCBLA 1996).

Screening levels for perchlorate calculated using leaching equation in USEPA Soil Screening Guidance and assumed Dilution/Attenuation Factor of 20 (see text).

TABLE H-1. CRITERIA FOR ASSIGNMENT
OF SOIL GROSS CONTAMINATION CEILING LEVELS

Soil Category	Criteria	Gross Contamination Ceiling Level (mg/kg)
Surface Soils		
Residential/Parkland/Agricultural	Odor Index $\geq$ 100 OR no Odor Index and Vapor Pressure $\geq$ 1 Torr OR no data	100
	0.1 $\leq$ Odor Index < 100 OR no Odor Index and Vapor Pressure < 1 Torr	500
	Odor Index < 0.1 OR non-odorous chemical	1000
Industrial/Commercial	Odor Index $\geq$ 100 OR no Odor Index and Vapor Pressure $\geq$ 1 Torr OR no data	500
	0.1 $\leq$ Odor Index < 100 OR no Odor Index and Vapor Pressure < 1 Torr	1000
	Odor Index < 0.1 OR non-odorous chemical	2500
Subsurface Soils		
Residential/Parkland/Agricultural	Odor Index $\geq$ 100 OR no Odor Index and Vapor Pressure $\geq$ 1 Torr OR no data	500
	0.1 $\leq$ Odor Index < 100 OR no Odor Index and Vapor Pressure < 1 Torr	1000
	Odor Index < 0.1 OR non-odorous chemical	2500
Industrial/Commercial	Odor Index $\geq$ 100 OR no Odor Index and Vapor Pressure $\geq$ 1 Torr OR no data	1000
	0.1 $\leq$ Odor Index < 100 OR no Odor Index and Vapor Pressure < 1 Torr	2500
	Odor Index < 0.1 OR non-odorous chemical	5000

Modified from Ontario Ministry of Environment and Energy (MOEE 1996) and Massachusetts Department of Environmental Protection (MADEP 1994).
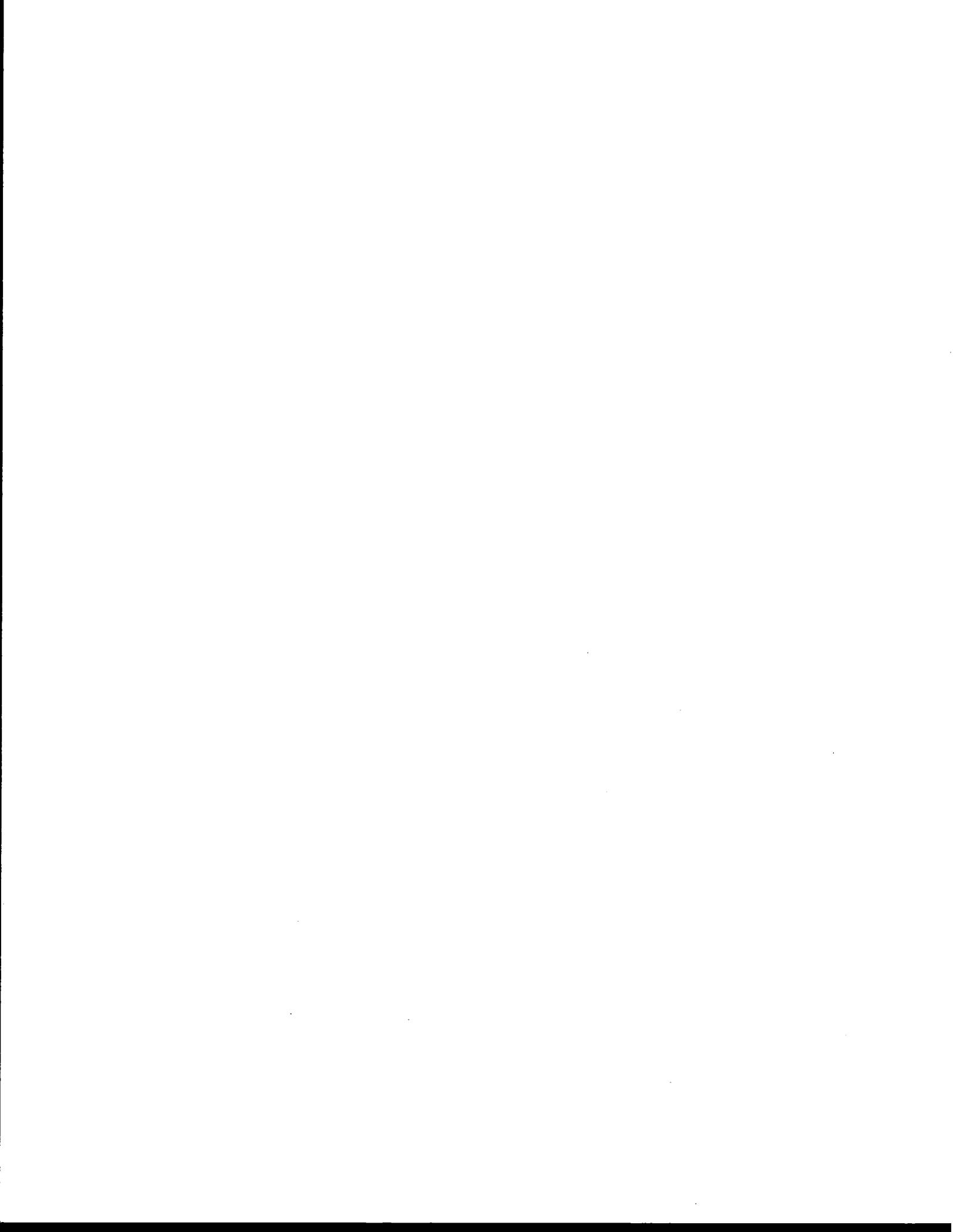
TABLE H-2. COMPONENTS FOR SHALLOW SOIL GROSS CONTAMINATION CEILING LEVELS (mg/kg)

CHEMICAL PARAMETER	'Residential Gross Contamination Ceiling Level	Industrial/ Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m³)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
ACENAPHTHENE	1.0E+03	2.5E+03	NA	4.5E-03	5.13E+02	8.00E-02	5.63E-02
ACENAPHTHYLENE	5.0E+02	1.0E+03	NA	2.9E-02	-	-	-
ACETONE	5.0E+02	1.0E+03	1.0E-05	2.70E+02	3.09E+04	1.30E+01	2.08E+01
ALDRIN	1.0E+03	2.5E+03	NA	2.3E-05	2.63E+02	1.70E-02	1.35E-03
ANTHRACENE	5.0E+02	1.0E+03	NA	1.7E-05	-	-	-
ANTIMONY	1.0E+03	2.5E+03	NA	-	-	-	-
ARSENIC	1.0E+03	2.5E+03	NA	-	-	-	-
BARIUM	1.0E+03	2.5E+03	NA	-	-	-	-
BENZENE	5.0E+02	1.0E+03	8.7E+02	9.50E+01	4.89E+03	1.50E+00	6.33E+01
BENZO(a)ANTHRACENE	5.0E+02	1.0E+03	NA	2.2E-08	-	-	-
BENZO(b)FLUORANTHENE	5.0E+02	1.0E+03	NA	5.0E-07	-	-	-
BENZO(k)FLUORANTHENE	5.0E+02	1.0E+03	NA	9.6E-11	-	-	-
BENZO(g,h,i)PERYLENE	5.0E+02	1.0E+03	NA	1.1E-10	-	-	-
BENZO(a)PYRENE	5.0E+02	1.0E+03	NA	5.6E-09	-	-	-
BERYLLIUM	1.0E+03	2.5E+03	NA	-	-	-	-
BIPHENYL, 1,1-	5.0E+02	1.0E+03	NA	5.00E-03	6.00E+01	9.50E-03	5.26E-01
BIS(2-CHLOROETHYL)ETHER	5.0E+02	1.0E+03	9.6E+03	7.1E-01	2.87E+02	4.9E-02	1.45E+01
BIS(2-CHLOROISOPROPYL)ETHER	5.0E+02	7.9E+02	7.9E+02	8.5E-01	2.24E+03	3.20E-01	2.66E+00
BIS(2-ETHYLHEXYL)PHTHALATE	5.0E+02	1.0E+03	NA	6.2E-08	-	-	-
BORON	no criteria	no critiera	NA	-	-	-	-
BROMODICHLOROMETHANE	1.0E+03	2.5E+03	3.0E+03	5.00E+01	1.10E+07	1.68E+03	2.98E-02
BROMOFORM	5.0E+02	1.0E+03	NA	5.60E+00	1.35E+04	1.30E+00	4.31E+00
BROMOMETHANE	5.0E+02	1.0E+03	3.1E+03	1.42E+03	8.00E+04	2.00E+01	7.10E+01
CADMIUM	1.0E+03	2.5E+03	NA	-	-	-	-
CARBON TETRACHLORIDE	5.0E+02	1.0E+03	1.1E+03	1.13E+02	6.30E+04	1.00E+01	1.13E+01
CHLORDANE	1.0E+03	2.5E+03	NA	1.0E-05	8.40E+00	4.92E-04	2.03E-02
CHLOROANILINE, p-	1.0E+03	2.5E+03	NA	1.0E-05	-	-	-
CHLOROBENZENE	5.0E+02	6.8E+02	6.8E+02	1.18E+01	1.00E+03	2.20E-01	5.36E+01
CHLOROETHANE	5.0E+02	1.0E+03	1.6E+03	1.01E+03	3.80E+05	1.40E+02	7.20E+00
CHLOROFORM	5.0E+02	1.0E+03	2.9E+03	1.60E+02	4.22E+05	8.50E+01	1.88E+00
CHLOROMETHANE	5.0E+02	5.0E+02	4.1E+03	4.30E+03	-	-	-
CHLOROPHENOL, 2-	1.0E+02	5.0E+02	5.5E+04	1.42E+00	1.90E+01	3.60E-03	3.94E+02
CHROMIUM (Total)	1.0E+03	2.5E+03	NA	-	-	-	-
CHROMIUM III	1.0E+03	2.5E+03	NA	-	-	-	-
CHROMIUM VI	1.0E+03	2.5E+03	NA	-	-	-	-
CHRYSENE	1.0E+03	2.5E+03	NA	6.3E-07	-	-	-
COBALT	1.0E+03	2.5E+03	NA	-	-	-	-
COPPER	1.0E+03	2.5E+03	NA	-	-	-	-
CYANIDE (Free)	1.0E+02	5.0E+02	NA	6.20E+02	6.52E+02	5.80E-01	1.07E+03

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Table H-2 (Shallow Soils)

TABLE H-2. COMPONENTS FOR SHALLOW SOIL GROSS CONTAMINATION CEILING LEVELS
(mg/kg)

CHEMICAL PARAMETER	[1]Residential Gross Contamination Ceiling Level	Industrial/ Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m³)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
DIBENZO(a,h)ANTHRACENE	5.0E+02	1.0E+03	NA	1.0E-10	-	-	-
DIBROMOCHLOROMETHANE	1.0E+02	5.0E+02	NA	7.60E+01	-	-	-
1,2-DIBROMO-3-CHLOROPROPANE	5.0E+02	1.0E+03	1.1E+03	8.00E-01	-	-	-
DIBROMOETHANE, 1,2-	5.0E+02	1.0E+03	NA	1.20E+01	2.00E+05	2.60E+01	4.62E-01
DICHLOROBENZENE, 1,2-	6.0E+02	6.0E+02	6.0E+02	1.50E+00	3.05E+05	5.00E+01	3.00E-02
DICHLOROBENZENE, 1,3-	1.0E+02	3.8E+02	6.0E+02	2.30E+00	-	-	-
DICHLOROBENZENE, 1,4-	5.0E+02	1.0E+03	NA	1.80E+00	1.10E+03	1.80E-01	1.00E+01
DICHLOROBENZIDINE, 3,3-	5.0E+02	1.0E+03	NA	4.5E-09	-	-	-
DICHLORODIPHENYLDICHLOROETHANE (DDD)	5.0E+02	1.0E+03	NA	1.0E-06	-	-	-
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	5.0E+02	1.0E+03	NA	6.5E-06	-	-	-
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.0E+03	2.5E+03	NA	5.5E-06	-	-	-
DICHLOROETHANE, 1,1-	5.0E+02	1.0E+03	1.7E+03	2.34E+02	1.25E+05	3.00E+01	7.80E+00
DICHLOROETHANE, 1,2-	5.0E+02	1.0E+03	1.8E+03	7.90E+01	2.42E+03	5.90E-01	1.34E+02
DICHLOROETHYLENE, 1,1-	5.0E+02	1.0E+03	1.5E+03	5.91E+02	2.00E+06	5.00E+02	1.18E+00
DICHLOROETHYLENE, Cis 1,2-	1.0E+02	5.0E+02	1.2E+03	2.15E+02	-	-	-
DICHLOROETHYLENE, Trans 1,2-	5.0E+02	1.0E+03	3.1E+03	3.31E+02	6.73E+04	1.70E+01	1.95E+01
DICHLOROPHENOL, 2,4-	5.0E+02	1.0E+03	NA	6.7E-02	1.40E+03	2.10E-01	3.19E-01
DICHLOROPROPANE, 1,2-	1.0E+02	5.0E+02	1.1E+03	4.20E+01	1.19E+03	2.50E-01	1.68E+02
DICHLOROPROPENE, 1,3-	5.0E+02	1.0E+03	1.4E+03	4.30E+01	4.16E+03	1.00E+00	4.30E+01
DIELDRIN	1.0E+03	2.5E+03	NA	1.8E-08	-	-	-
DIETHYLPHTHALATE	5.0E+02	1.0E+03	NA	3.5E-04	-	-	-
DIMETHYLPHTHALATE	5.0E+02	1.0E+03	NA	1.7E-03	-	-	-
DIMETHYLPHENOL, 2,4-	1.0E+02	5.0E+02	NA	9.8E-02	1.00E+00	1.97E-04	4.97E+02
DINITROPHENOL, 2,4-	5.0E+02	1.0E+03	-	1.5E-05	-	-	-
DINITROTOLUENE, 2,4-	5.0E+02	1.0E+03	NA	5.1E-03	-	-	-
1,4 DIOXANE	5.0E+02	1.0E+03	NA	3.70E+01	6.12E+05	1.70E+02	2.18E-01
DIOXIN (2,3,7,8-TCDD)	no criteria	no criteria	NA	-	-	-	-
ENDOSULFAN	5.0E+02	1.0E+03	NA	1.0E-05	-	-	-
ENDRIN	5.0E+02	1.0E+03	NA	2.0E-07	-	-	-
ETHANOL	5.0E+02	1.0E+03	-	5.65E+01	1.92E+04	1.00E+01	5.65E+00
ETHYLBENZENE	4.0E+02	4.0E+02	4.0E+02	1.00E+01	2.00E+03	4.50E-01	2.22E+01
FLUORANTHENE	5.0E+02	1.0E+03	NA	5.0E-06	-	-	-
FLUORENE	5.0E+02	1.0E+03	NA	3.2E-04	-	-	-
HEPTACHLOR	1.0E+03	2.5E+03	NA	3.0E-04	3.00E+02	2.00E-02	1.50E-02
HEPTACHLOR EPOXIDE	1.0E+03	2.5E+03	NA	2.6E-06	3.00E+02	1.90E-02	1.37E-04
HEXACHLOROBENZENE	5.0E+02	1.0E+03	NA	1.1E-05	-	-	-
HEXACHLOROBUTADIENE	5.0E+02	1.0E+03	NA	1.50E-01	1.20E+04	1.10E+00	1.36E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	5.0E+02	1.0E+03	NA	9.4E-06	-	-	-
HEXACHLOROETHANE	5.0E+02	1.0E+03	NA	2.1E-01	-	-	-

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Table H-2 (Shallow Soils)

TABLE H-2. COMPONENTS FOR SHALLOW SOIL GROSS CONTAMINATION CEILING LEVELS (mg/kg)

CHEMICAL PARAMETER	[1]Residential Gross Contamination Ceiling Level	Industrial/ Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m³)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
INDENO(1,2,3-cd)PYRENE	5.0E+02	1.0E+03	NA	1.0E-06	-	-	-
LEAD	1.0E+03	2.5E+03	NA	-	-	-	-
MERCURY	5.0E+02	1.0E+03	NA	2.0E-03	-	-	-
METHOXYCHLOR	5.0E+02	1.0E+03	NA	1.4E-06	-	-	-
METHYLENE CHLORIDE	5.0E+02	1.0E+03	2.4E+03	4.29E+02	5.60E+05	1.60E+02	2.68E+00
METHYL ETHYL KETONE	5.0E+02	1.0E+03	3.4E+04	1.00E+02	3.20E+04	1.10E+01	9.09E+00
METHYL ISOBUTYL KETONE	1.0E+02	5.0E+02	1.7E+04	1.00E+01	4.20E+02	1.00E-01	1.00E+02
METHYL MERCURY	1.0E+02	5.0E+02	NA	-	-	-	-
METHYLNAPHTHALENE (total 1- & 2-)	5.0E+02	1.0E+03	NA	6.8E-02	6.80E+01	1.15E-02	5.91E+00
METHYL TERT BUTYL ETHER	1.0E+02	5.0E+02	2.1E+04	2.45E+02	5.30E+02	1.30E-01	1.88E+03
MOLYBDENUM	1.0E+03	2.5E+03	NA	-	-	-	-
NAPHTHALENE	5.0E+02	1.0E+03	NA	8.2E-02	4.40E+02	8.40E-02	9.76E-01
NICKEL	1.0E+03	2.5E+03	NA	-	-	-	-
PENTACHLOROPHENOL	5.0E+02	1.0E+03	NA	1.1E-04	-	-	-
PERCHLORATE	1.0E+03	2.5E+03	NA	-	-	-	-
PHENANTHRENE	5.0E+02	1.0E+03	NA	9.6E-04	5.50E+01	7.42E-03	1.29E-01
PHENOL	5.0E+02	1.0E+03	NA	3.50E-01	1.56E+02	4.00E-02	8.75E+00
POLYCHLORINATED BIPHENYLS (PCBs)	5.0E+02	1.0E+03	NA	4.9E-04 to 6.7E-03	-	-	-
PYRENE	5.0E+02	1.0E+03	NA	2.5E-06	-	-	-
SELENIUM	1.0E+03	2.5E+03	NA	-	-	-	-
SILVER	1.0E+03	2.5E+03	NA	-	-	-	-
STYRENE	5.0E+02	1.0E+03	1.5E+03	5.00E+00	1.36E+03	3.00E-01	1.67E+01
tert-BUTYL ALCOHOL	1.0E+02	5.0E+02	3.2E+05	4.20E+01	-	-	-
TETRACHLOROETHANE, 1,1,1,2-	1.0E+02	5.0E+02	2.0E+03	1.20E+01	-	-	-
TETRACHLOROETHANE, 1,1,2,2-	5.0E+02	1.0E+03	2.0E+03	4.00E+00	1.05E+04	1.50E+00	2.67E+00
TETRACHLOROETHYLENE	2.3E+02	2.3E+02	2.3E+02	1.90E+01	3.17E+04	4.68E+00	4.06E+00
THALLIUM	1.0E+03	2.5E+03	NA	-	-	-	-
TOLUENE	5.0E+02	6.5E+02	6.5E+02	2.80E+01	3.00E+04	8.00E+00	3.50E+00
TOXAPHENE	5.0E+02	1.0E+03	NA	4.00E-01	-	-	-
TPH (gasolines)	1.0E+02	5.0E+02	-	3.00E+02	1.00E+02	2.20E-02	1.36E+04
TPH (middle distillates)	1.0E+02	5.0E+02	-	5.00E+00	1.00E+03	1.41E-02	3.55E+02
TPH (residual fuels)	5.0E+02	2.5E+03	-	-	-	-	-
TRICHLOROBENZENE, 1,2,4-	5.0E+02	1.0E+03	NA	2.9E-01	2.20E+04	2.96E+00	9.80E-02
TRICHLOROETHANE, 1,1,1-	5.0E+02	1.0E+03	1.2E+03	1.00E+02	6.51E+04	1.20E+01	8.33E+00
TRICHLOROETHANE, 1,1,2-	1.0E+02	5.0E+02	1.8E+03	2.25E+01	-	-	-
TRICHLOROETHYLENE	5.0E+02	1.3E+03	1.3E+03	7.70E+01	1.36E+06	2.49E+02	3.09E-01
TRICHLOROPHENOL, 2,4,5-	1.0E+02	5.0E+02	NA		-	-	-
TRICHLOROPHENOL, 2,4,6-	5.0E+02	1.0E+03	NA	1.2E-02	3.00E-01	3.60E-05	3.33E+02
VANADIUM	1.0E+03	2.5E+03	NA	-	-	-	-

TABLE H-2. COMPONENTS FOR SHALLOW SOIL GROSS CONTAMINATION CEILING LEVELS (mg/kg)

CHEMICAL PARAMETER	[1]Residential Gross Contamination Ceiling Level	Industrial/ Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m^3)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
VINYL CHLORIDE	5.0E+02	1.0E+03	1.2E+03	2.58E+03	7.71E+05	2.94E+02	8.78E+00
XYLENES	4.2E+02	4.2E+02	4.2E+02	6.00E+00	4.41E+02	1.00E-01	6.00E+01
ZINC	1.0E+03	2.5E+03	NA	-	-	-	-

Notes:

1. "Residential Land Use" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

Odor Index = VP/ORT in ppm-v

Physio-chemical constants Ontario MOEE (MOEE 1996) except as noted.

Physio-chemical constants for cloroethane and chloromethane from ATSDR Toxicological Profiles (ATSDR 2001).

Odor Recognition Threshold in parts per million - volume (ppm-v = (concentration in mg/m3) x (24/molecular weight)).

TPH -Total Petroleum Hydrocarbons.   See text for discussion of different TPH categories.

Ceiling Level: Based on comparison of vapor pressure and odor index to Table H-1 or saturation limit, if lower.

Saturation limits calculated using equation in USEPA Region IX PRG guidance (for chemicals that are liquid at ambient temperatures and pressures; refer to Appendix 2).

Odor Threshold for ethanol of 10 ppmv from U.S. Coast Guard Chemical Hazards Response Information System (USCG 1999).

Odor Threshold of 0.13 ppmv for MTBE from information in CaEPA Public Health Goal for MTBE (CalEPA 1999).

TPH VP values from NIOSH (2005); ORT values from ATSDR (2001a).

Ceiling Levels for TPH after guidance from Massachusetts Department of Environmental Protection (MADEP 1997a). Adjust as needed in field.

References for vapor pressure and odor threshold data (in order of use):

1. Ontario Ministry of Environment and Energy (MOEE 1996).

2. Massachusetts Department of Environmental Protection (MADEP 1994).

3. Agency for Toxic Substances and Disease Registry (ATSDR 2001).

4. Vapor Pressure for 1,4 Dioxane from "Solvent Stabilizers - White Paper" (Mohr 2001). Odor Threshold from US Department of Health and Human Services, National Toxicology Program (USDHHS, 2001).

TABLE H-3. COMPONENTS FOR DEEP SOIL GROSS CONTAMINATION CEILING LEVELS (mg/kg)

CHEMICAL PARAMETER	¹Residential Gross Contamination Ceiling Level	Industrial/ Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m³)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
ACENAPHTHENE	2.5E+03	5.0E+03	NA	4.5E-03	5.13E+02	8.00E-02	5.63E-02
ACENAPHTHYLENE	1.0E+03	2.5E+03	NA	2.9E-02	-	-	-
ACETONE	1.0E+03	2.5E+03	1.0E+05	2.70E+02	3.09E+04	1.30E+01	2.08E+01
ALDRIN	2.5E+03	5.0E+03	NA	2.3E-05	2.63E+02	1.70E-02	1.35E-03
ANTHRACENE	1.0E+03	2.5E+03	NA	1.7E-05	-	-	-
ANTIMONY	2.5E+03	5.0E+03	NA	-	-	-	-
ARSENIC	2.5E+03	5.0E+03	NA	-	-	-	-
BARIUM	2.5E+03	5.0E+03	NA	-	-	-	-
BENZENE	1.0E+03	1.1E+03	8.7E+02	9.50E+01	4.89E+03	1.50E+00	6.33E+01
BENZO(a)ANTHRACENE	1.0E+03	2.5E+03	NA	2.2E-08	-	-	-
BENZO(b)FLUORANTHENE	1.0E+03	2.5E+03	NA	5.0E-07	-	-	-
BENZO(k)FLUORANTHENE	1.0E+03	2.5E+03	NA	9.6E-11	-	-	-
BENZO(g,h,i)PERYLENE	1.0E+03	2.5E+03	NA	1.1E-10	-	-	-
BENZO(a)PYRENE	1.0E+03	2.5E+03	NA	5.6E-09	-	-	-
BERYLLIUM	2.5E+03	5.0E+03	NA	-	-	-	-
BIPHENYL, 1,1-	1.0E+03	2.5E+03	NA	5.00E-03	6.00E+01	9.50E-03	5.26E-01
BIS(2-CHLOROETHYL)ETHER	1.0E+03	2.5E+03	9.6E+03	7.1E-01	2.87E+02	4.9E-02	1.45E+01
BIS(2-CHLOROISOPROPYL)ETHER	7.9E+02	7.9E+02	7.9E+02	8.5E-01	2.24E+03	3.20E-01	2.66E+00
BIS(2-ETHYLHEXYL)PHTHALATE	1.0E+03	2.5E+03	NA	6.2E-08	-	-	-
BORON	no criteria	no critiera	NA	-	-	-	-
BROMODICHLOROMETHANE	2.5E+03	3.0E+03	3.0E+03	5.00E+01	1.10E+07	1.68E+03	2.98E-02
BROMOFORM	1.0E+03	2.5E+03	NA	5.60E+00	1.35E+04	1.30E+00	4.31E+00
BROMOMETHANE	1.0E+03	2.5E+03	3.1E+03	1.42E+03	8.00E+04	2.00E+01	7.10E+01
CADMIUM	2.5E+03	5.0E+03	NA	-	-	-	-
CARBON TETRACHLORIDE	1.0E+03	1.1E+03	1.1E+03	1.13E+02	6.30E+04	1.00E+01	1.13E+01
CHLORDANE	2.5E+03	5.0E+03	NA	1.0E-05	8.40E+00	4.92E-04	2.03E-02
CHLOROANILINE, p-	2.5E+03	5.0E+03	NA	1.0E-05	-	-	-
CHLOROBENZENE	6.8E+02	6.8E+02	6.8E+02	1.18E+01	1.00E+03	2.20E-01	5.36E+01
CHLOROETHANE	1.0E+03	2.5E+03	1.6E+03	1.01E+03	3.80E+05	1.40E+02	7.20E+00
CHLOROFORM	1.0E+03	2.5E+03	2.9E+03	1.60E+02	4.22E+05	8.50E+01	1.88E+00
CHLOROMETHANE	5.0E+02	1.0E+03	4.1E+03	4.30E+03	-	-	-
CHLOROPHENOL, 2-	5.0E+02	1.0E+03	5.5E+04	1.42E+00	1.90E+01	3.60E-03	3.94E+02
CHROMIUM (Total)	2.5E+03	5.0E+03	NA				
CHROMIUM III	2.5E+03	5.0E+03	NA				
CHROMIUM VI	2.5E+03	5.0E+03	NA				
CHRYSENE	2.5E+03	5.0E+03	NA	6.3E-07	-	-	-
COBALT	2.5E+03	5.0E+03	NA	-	-	-	-
COPPER	2.5E+03	5.0E+03	NA	-	-	-	-
CYANIDE (Free)	5.0E+02	1.0E+03	NA	6.20E+02	6.52E+02	5.80E-01	1.07E+03

TABLE H-3. COMPONENTS FOR DEEP SOIL GROSS CONTAMINATION CEILING LEVELS (mg/kg)

CHEMICAL PARAMETER	[1]Residential Gross Contamination Ceiling Level	Industrial/Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m³)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
DIBENZO[a,h]ANTHTRACENE	1.0E+03	2.5E+03	NA	1.0E-10	-	-	-
DIBROMOCHLOROMETHANE	5.0E+02	1.0E+03	NA	7.60E+01	-	-	-
1,2-DIBROMO-3-CHLOROPROPANE	1.0E+03	2.5E+03	1.1E+03	8.00E-01	-	-	-
DIBROMOETHANE, 1,2-	1.0E+03	2.5E+03	NA	1.20E+01	2.00E+05	2.60E-01	4.62E-01
DICHLOROBENZENE, 1,2-	6.0E+02	6.0E+02	6.0E+02	1.50E+00	3.05E+05	5.00E-01	3.00E-02
DICHLOROBENZENE, 1,3-	6.0E+02	6.0E+02	6.0E+02	2.30E+00	-	-	-
DICHLOROBENZENE, 1,4-	1.0E+03	2.5E+03	NA	1.80E+00	1.10E+03	1.80E-01	1.00E+01
DICHLOROBENZIDINE, 3,3-	1.0E+03	2.5E+03	NA	4.5E-09	-	-	-
DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.0E+03	2.5E+03	NA	1.0E-06	-	-	-
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.0E+03	2.5E+03	NA	6.5E-06	-	-	-
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	2.5E+03	5.0E+03	NA	5.5E-06	-	-	-
DICHLOROETHANE, 1,1-	1.0E+03	1.7E+03	1.7E+03	2.34E+02	1.25E+05	3.00E-01	7.80E+00
DICHLOROETHANE, 1,2-	1.0E+03	2.5E+03	1.8E+03	7.90E+01	2.42E+03	5.90E-01	1.34E+02
DICHLOROETHYLENE, 1,1-	1.0E+03	1.5E+03	1.5E+03	5.91E+02	2.00E+06	5.00E+02	1.18E+00
DICHLOROETHYLENE, Cis 1,2-	5.0E+02	1.0E+03	1.2E+03	2.15E+02	-	-	-
DICHLOROETHYLENE, Trans 1,2-	1.0E+03	2.5E+03	3.1E+03	3.31E+02	6.73E+04	1.70E+01	1.95E+01
DICHLOROPHENOL, 2,4-	1.0E+03	2.5E+03	NA	6.7E-02	1.40E+03	2.10E-01	3.19E-01
DICHLOROPROPANE, 1,2-	5.0E+02	1.0E+03	1.1E+03	4.20E-01	1.19E+03	2.50E-01	1.68E+02
DICHLOROPROPENE, 1,3-	1.0E+03	1.4E+03	1.4E+03	4.30E-01	4.16E+03	1.00E+00	4.30E+01
DIELDRIN	2.5E+03	5.0E+03	NA	1.8E-08	-	-	-
DIETHYLPHTHALATE	1.0E+03	2.5E+03	NA	3.5E-04	-	-	-
DIMETHYLPHTHALATE	1.0E+03	2.5E+03	NA	1.7E-03	-	-	-
DIMETHYLPHENOL, 2,4-	5.0E+02	1.0E+03	NA	9.8E-02	1.00E+00	1.97E-04	4.97E+02
DINITROPHENOL, 2,4-	1.0E+03	2.5E+03	4.0E+02	1.00E+01	-	-	-
DINITROTOLUENE, 2,4-	1.0E+03	2.5E+03	NA	1.5E-05	-	-	-
1,4 DIOXANE	1.0E+03	2.5E+03	NA	5.1E-03	-	-	-
DIOXIN (2,3,7,8-TCDD)	no criteria	no criteria	NA	3.70E-01	6.12E+05	1.70E+02	2.18E-01
ENDOSULFAN	1.0E+03	2.5E+03	NA	1.0E-05	-	-	-
ENDRIN	1.0E+03	2.5E+03	NA	2.0E-07	-	-	-
ETHANOL	1.0E+03	2.5E+03	NA	5.65E+01	1.92E+04	1.00E+01	5.65E+00
ETHYLBENZENE	4.0E+02	4.0E+02	4.0E+02	1.00E+01	2.00E+03	4.50E-01	2.22E+01
FLUORANTHENE	1.0E+03	2.5E+03	NA	5.0E-06	-	-	-
FLUORENE	1.0E+03	2.5E+03	NA	3.2E-04	-	-	-
HEPTACHLOR	2.5E+03	5.0E+03	NA	3.0E-04	3.00E+02	2.00E-02	1.50E-02
HEPTACHLOR EPOXIDE	2.5E+03	5.0E+03	NA	2.6E-06	3.00E+02	1.90E-02	1.37E-04
HEXACHLOROBENZENE	1.0E+03	2.5E+03	NA	1.1E-05	-	-	-
HEXACHLOROBUTADIENE	1.0E+03	2.5E+03	NA	1.50E-01	-	-	-
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	1.0E+03	2.5E+03	NA	9.4E-06	1.20E+04	1.10E+00	1.36E-01
HEXACHLOROETHANE	1.0E+03	2.5E+03	NA	2.1E-01	-	-	-

TABLE H-3. COMPONENTS FOR DEEP SOIL GROSS CONTAMINATION CEILING LEVELS
(mg/kg)

CHEMICAL PARAMETER	[1]Residential Gross Contamination Ceiling Level	Industrial/ Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m³)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
INDENO(1,2,3-cd)PYRENE	1.0E+03	2.5E+03	NA	1.0E-06	-	-	-
LEAD	2.5E+03	5.0E+03	NA	-	-	-	-
MERCURY	1.0E+03	2.5E+03	NA	2.0E-03	-	-	-
METHOXYCHLOR	1.0E+03	2.5E+03	NA	1.4E-06	-	-	-
METHYLENE CHLORIDE	1.0E+03	2.3E+03	2.4E+03	4.29E+02	5.60E+05	1.60E+02	2.68E+00
METHYL ETHYL KETONE	1.0E+03	2.5E+03	3.4E+04	1.00E+02	3.20E+04	1.10E+01	9.09E+00
METHYL ISOBUTYL KETONE	5.0E+02	1.0E+03	1.7E+04	1.00E+01	4.20E+02	1.00E-01	1.00E+02
METHYL MERCURY	5.0E+02	1.0E+03	NA	-	-	-	-
METHYLNAPHTHALENE (total 1- & 2-)	1.0E+03	2.5E+03	NA	6.8E-02	6.80E+01	1.15E-02	5.91E+00
METHYL TERT BUTYL ETHER	5.0E+02	1.0E+03	2.1E+04	2.45E+02	5.30E+02	1.30E-01	1.88E+03
MOLYBDENUM	2.5E+03	5.0E+03	NA	-	-	-	-
NAPHTHALENE	1.0E+03	2.5E+03	NA	8.2E-02	4.40E+02	8.40E-02	9.76E-01
NICKEL	2.5E+03	5.0E+03	NA	-	-	-	-
PENTACHLOROPHENOL	1.0E+03	2.5E+03	NA	1.1E-04	-	-	-
PERCHLORATE	2.5E+03	5.0E+03	NA	-	-	-	-
PHENANTHRENE	1.0E+03	2.5E+03	NA	9.6E-04	5.50E+01	7.42E-03	1.29E-01
PHENOL	1.0E+03	2.5E+03	NA	3.50E-01	1.56E+02	4.00E-02	8.75E+00
POLYCHLORINATED BIPHENYLS (PCBs)	1.0E+03	2.5E+03	NA	4.9E-04 to 6.7E-03	-	-	-
PYRENE	1.0E+03	2.5E+03	NA	2.5E-06	-	-	-
SELENIUM	2.5E+03	5.0E+03	NA	-	-	-	-
SILVER	2.5E+03	5.0E+03	NA	-	-	-	-
STYRENE	1.0E+03	1.5E+03	1.5E+03	5.00E+00	1.36E+03	3.00E-01	1.67E+01
tert-BUTYL ALCOHOL	5.0E+02	1.0E+03	3.2E+05	4.20E+01	-	-	-
TETRACHLOROETHANE, 1,1,1,2-	5.0E+02	1.0E+03	2.0E+03	1.20E+01	-	-	-
TETRACHLOROETHANE, 1,1,2,2-	1.0E+03	2.0E+03	2.0E+03	4.00E+00	1.05E+04	1.50E+00	2.67E+00
TETRACHLOROETHYLENE	2.3E+02	2.3E+02	2.3E+02	1.90E+01	3.17E+04	4.68E+00	4.06E+00
THALLIUM	2.5E+03	5.0E+03	NA	-	-	-	-
TOLUENE	6.5E+02	6.5E+02	6.5E+02	2.80E+01	3.00E+04	8.00E+00	3.50E+00
TOXAPHENE	1.0E+03	2.5E+03	NA	4.00E-01	-	-	-
TPH (gasolines)	5.0E+03	5.0E+03	-	3.00E+02	1.00E+02	2.20E-02	1.36E+04
TPH (middle distillates)	5.0E+03	5.0E+03	-	5.00E+00	1.00E+03	1.41E-02	3.55E+02
TPH (residual fuels)	5.0E+03	5.0E+03	-	-	-	-	-
TRICHLOROBENZENE, 1,2,4-	1.0E+03	2.5E+03	NA	2.9E-01	2.20E+04	2.96E+00	9.80E-02
TRICHLOROETHANE, 1,1,1-	1.0E+03	1.2E+03	1.2E+03	1.00E+02	6.51E+04	1.20E+01	8.33E+00
TRICHLOROETHANE, 1,1,2-	5.0E+02	1.0E+03	1.8E+03	2.25E+01	-	-	-
TRICHLOROETHYLENE	1.0E+03	1.3E+03	1.3E+03	7.70E+01	1.36E+06	2.49E+02	3.09E-01
TRICHLOROPHENOL, 2,4,5-	5.0E+02	1.0E+03	NA	-	-	-	-
TRICHLOROPHENOL, 2,4,6-	1.0E+03	2.5E+03	NA	1.2E-02	3.00E-01	3.60E-05	3.33E+02
VANADIUM	2.5E+03	5.0E+03	NA	-	-	-	-

TABLE H-3. COMPONENTS FOR DEEP SOIL GROSS CONTAMINATION CEILING LEVELS
(mg/kg)

CHEMICAL PARAMETER	¹Residential Gross Contamination Ceiling Level	Industrial/ Commercial Gross Contamination Ceiling Level	Soil Saturation Limit (mg/kg)	Vapor Pressure (VP) (Torr @ 20-30 °C)	50 Percentile Odor Recognition Threshold (ORT) (ug/m³)	50 Percentile Odor Recognition Threshold (ORT) (ppm-v)	Odor Index
VINYL CHLORIDE	1.0E+03	2.5E+03	1.2E+03	2.58E+03	7.71E+05	2.94E+02	8.78E+00
XYLENES	4.2E+02	4.2E+02	4.2E+02	6.00E+00	4.41E+02	1.00E-01	6.00E+01
ZINC	2.5E+03	5.0E+03	NA	-	-	-	-

Notes:

1. "Residential Land Use" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

Odor Index = VP/ORT in ppm-v

Physio-chemical constants Ontario MOEE (MOEE 1996) except as noted.

Physio-chemical constants for cloroethane and chloromethane from ATSDR Toxicological Profiles (ATSDR 2001).

Odor Recognition Threshold in parts per million - volume (ppm-v = (concentration in mg/m3) x (24/molecular weight)).

TPH - Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

Ceiling Level: Based on comparison of vapor pressure and odor index to Table H-1 or saturation limit, if lower.

Saturation limits calculated using equation in USEPA Region IX PRG guidance (for chemicals that are liquid at ambient temperatures and pressures; refer to Appendix 2).

Odor Threshold for ethanol of 10 ppmv from U.S. Coast Guard Chemical Hazards Response Information System (USCG 1999).

Odor Threshold of 0.13 ppmv for MTBE from information in CaEPA Public Health Goal for MTBE (CalEPA 1999).

TPH VP values from NIOSH (2005); ORT values from ATSDR (2001a).

Ceiling Levels for TPH after guidance from Massachusetts Department of Environmental Protection (MADEP 1997a). Adjust as needed in field.

References for vapor pressure and odor threshold data (in order of use):

1. Ontario Ministry of Environment and Energy (MOEE 1996).
2. Massachusetts Department of Environmental Protection (MADEP 1994).
3. Agency for Toxic Substances and Disease Registry (ATSDR 2001).
4. National Library of Medicine, Hazardous Substances Data Bank (NLM 2000).
5. U.S. Department of Health and Human Services (NIOSH 2005).

TABLE I-1. GROUNDWATER CEILING LEVELS
(groundwater IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
ACENAPHTHENE	2.0E+01	Taste & Odors	2.1E+03	2.0E+01	Ontario MOEE	5.0E+04
ACENAPHTHYLENE	2.0E+03	Solubility	2.0E+03	-	-	5.0E+04
ACETONE	2.0E+04	Taste & Odors	5.0E+08	2.0E+04	Amoore & Hautala	5.0E+04
ALDRIN	8.5E+00	Solubility	8.5E+00	1.7E+01	Ontario MOEE	5.0E+04
ANTHRACENE	2.2E+01	Solubility	2.2E+01	-	-	5.0E+04
ANTIMONY	5.0E+04	Upper Limit		-	-	5.0E+04
ARSENIC	5.0E+04	Upper Limit		-	-	5.0E+04
BARIUM	5.0E+04	Upper Limit		-	-	5.0E+04
BENZENE	1.7E+02	Taste & Odors	8.8E+05	1.7E+02	Amoore & Hautala	5.0E+04
BENZO(a)ANTHRACENE	5.0E+00	Solubility	5.0E+00	-	-	5.0E+04
BENZO(b)FLUORANTHENE	7.0E+00	Solubility	7.0E+00	-	-	5.0E+04
BENZO(k)FLUORANTHENE	4.0E-01	Solubility	4.0E-01	-	-	5.0E+04
BENZO(g,h,i)PERYLENE	1.3E-01	Solubility	1.3E-01	-	-	5.0E+04
BENZO(a)PYRENE	1.9E+00	Solubility	1.9E+00	-	-	5.0E+04
BERYLLIUM	5.0E+04	Upper Limit		-	-	5.0E+04
BIPHENYL, 1,1-	5.0E-01	Taste & Odors	3.8E+03	5.0E-01	Amoore & Hautala	5.0E+04
BIS(2-CHLOROETHYL)ETHER	3.6E+02	Taste & Odors	8.6E+06	3.6E+02	Amoore & Hautala	5.0E+04
BIS(2-CHLOROISOPROPYL)ETHER	3.2E+02	Taste & Odors	8.5E+05	3.2E+02	Ontario MOEE	5.0E+04
BIS(2-ETHYLHEXYL)PHTHALATE	6.5E+02	Solubility	6.5E+02	-	-	5.0E+04
BORON	5.0E+04	Upper Limit	3.4E+06	-	-	5.0E+04
BROMODICHLOROMETHANE	5.0E+04	Upper Limit		-	-	5.0E+04
BROMOFORM	5.1E+02	Taste & Odors	1.6E+06	5.1E+02	Amoore & Hautala	5.0E+04
BROMOMETHANE	5.0E+04	Upper Limit	7.6E+06	-	-	5.0E+04
CADMIUM	5.0E+04	Upper Limit		-	-	5.0E+04
CARBON TETRACHLORIDE	5.2E+02	Taste & Odors	4.0E+05	5.2E+02	Amoore & Hautala	5.0E+04
CHLORDANE	2.5E+00	Taste & Odors	2.8E+01	2.5E+00	Ontario MOEE	5.0E+04
CHLOROANILINE, p-	5.0E+04	Upper Limit	1.3E+06	-	-	5.0E+04
CHLOROBENZENE	5.0E+01	Taste & Odors	2.4E+05	5.0E+01	Amoore & Hautala	5.0E+04
CHLOROETHANE	1.6E+01	Taste & Odors	2.9E+06	1.6E+01	Amoore & Hautala	5.0E+04
CHLOROFORM	2.4E+03	Taste & Odors	4.0E+06	2.4E+03	Amoore & Hautala	5.0E+04
CHLOROMETHANE	5.0E+04	Upper Limit	4.1E+06	-	-	5.0E+04
CHLOROPHENOL, 2-	1.8E-01	Taste & Odors	1.1E+07	1.8E-01	Ontario MOEE	5.0E+04
CHROMIUM (Total)	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM III	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM VI	5.0E+04	Upper Limit		-	-	5.0E+04
CHRYSENE	8.0E-01	Solubility	8.0E-01	-	-	5.0E+04
COBALT	5.0E+04	Upper Limit		-	-	5.0E+04

TABLE I-1. GROUNDWATER CEILING LEVELS
(groundwater IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
COPPER	1.0E+03	Taste & Odors		1.0E+03	CalDHS 2nd MCL	5.0E+04
CYANIDE (Free)	1.7E+02	Taste & Odors	5.0E+08	1.7E+02	Amoore & Hautala	5.0E+04
DIBENZO(a,h)ANTHTRACENE	2.5E-01	Solubility	2.5E-01	-	-	5.0E+04
DIBROMOCHLOROMETHANE	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
1,2-DIBROMO-3-CHLOROPROPANE	1.0E+01	Taste & Odors	6.0E+05	1.0E+01	Amoore & Hautala	5.0E+04
DIBROMOETHANE, 1,2-	5.0E+04	Upper Limit	1.7E+06	-	-	5.0E+04
DICHLOROBENZENE, 1,2-	1.0E+01	Taste & Odors	7.8E+04	1.0E+01	USEPA 2nd MCL	5.0E+04
DICHLOROBENZENE, 1,3-	5.0E+04	Upper Limit	7.8E+04	-	-	5.0E+04
DICHLOROBENZENE, 1,4-	5.0E+00	Taste & Odors	3.7E+04	5.0E+00	USEPA 2nd MCL	5.0E+04
DICHLOROBENZIDINE, 3,3-	1.6E+03	Solubility	1.6E+03	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.0E+01	Solubility	8.0E+01	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.0E+01	Solubility	2.0E+01	-	-	5.0E+04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.5E+00	Solubility	1.5E+00	3.5E+02	Ontario MOEE	5.0E+04
DICHLOROETHANE, 1,1-	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DICHLOROETHANE, 1,2-	7.0E+03	Taste & Odors	4.3E+06	7.0E+03	Amoore & Hautala	5.0E+04
DICHLOROETHYLENE, 1,1-	1.5E+03	Taste & Odors	1.1E+06	1.5E+03	Amoore & Hautala	5.0E+04
DICHLOROETHYLENE, Cis 1,2-	5.0E+04	Upper Limit	1.8E+06	-	-	5.0E+04
DICHLOROETHYLENE, Trans 1,2-	2.6E+02	Taste & Odors	3.2E+06	2.6E+02	Amoore & Hautala	5.0E+04
DICHLOROPHENOL, 2,4-	3.0E-01	Taste & Odors	2.3E+06	3.0E-01	Ontario MOEE	5.0E+04
DICHLOROPROPANE, 1,2-	1.0E+01	Taste & Odors	1.4E+06	1.0E+01	Ontario MOEE	5.0E+04
DICHLOROPROPENE, 1,3-	5.0E+04	Upper Limit	1.4E+06	-	-	5.0E+04
DIELDRIN	4.1E+01	Taste & Odors	9.3E+01	4.1E+01	Ontario MOEE	5.0E+04
DIETHYLPHTHALATE	5.0E+04	Upper Limit	4.5E+05	-	-	5.0E+04
DIMETHYLPHTHALATE	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DIMETHYLPHENOL, 2,4-	4.0E+02	Taste & Odors	3.9E+06	4.0E+02	Cal DHS AL	5.0E+04
DINITROPHENOL, 2,4-	5.0E+04	Upper Limit	2.8E+06	-	-	5.0E+04
DINITROTOLUENE, 2,4-	5.0E+04	Upper Limit	1.4E+05	-	-	5.0E+04
1,4 DIOXANE	5.0E+04	Upper Limit	5.0E+08	2.3E+05	Amoore & Hautala	5.0E+04
DIOXIN (2,3,7,8-TCDD)	7.0E+03	Solubility	7.0E+03	-	-	5.0E+04
ENDOSULFAN	7.5E+01	Solubility	7.5E+01	-	-	5.0E+04
ENDRIN	4.1E+01	Taste & Odors	1.3E+02	4.1E+01	Ontario MOEE	5.0E+04
ETHANOL	5.0E+04	Upper Limit	1.0E+09	7.6E+05	Amoore & Hautala	5.0E+04
ETHYLBENZENE	3.0E+01	Taste & Odors	8.5E+04	3.0E+01	USEPA 2nd MCL	5.0E+04
FLUORANTHENE	1.3E+02	Solubility	1.3E+02	-	-	5.0E+04
FLUORENE	9.5E+02	Solubility	9.5E+02	-	-	5.0E+04
HEPTACHLOR	2.0E+01	Taste & Odors	2.8E+01	2.0E+01	Ontario MOEE	5.0E+04
HEPTACHLOR EPOXIDE	1.8E+02	Solubility	1.8E+02	-	-	5.0E+04

TABLE I-1. GROUNDWATER CEILING LEVELS
(groundwater IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
HEXACHLOROBENZENE	5.5E+01	Solubility	5.5E+01	3.0E+03	Ontario MOEE	5.0E+04
HEXACHLOROBUTADIENE	6.0E+00	Taste & Odors	1.0E+03	6.0E+00	Ontario MOEE	5.0E+04
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	3.5E+03	Solubility	3.5E+03	1.2E+04	Ontario MOEE	5.0E+04
HEXACHLOROETHANE	1.0E+01	Taste & Odors	2.5E+04	1.0E+01	Amoore & Hautala	5.0E+04
INDENO(1,2,3-cd)PYRENE	2.7E-01	Solubility	2.7E-01	-	-	5.0E+04
LEAD	5.0E+04	Upper Limit		-	-	5.0E+04
MERCURY	5.0E+04	Upper Limit		-	-	5.0E+04
METHOXYCHLOR	2.0E+01	Solubility	2.0E+01	4.7E+03	Amoore & Hautala	5.0E+04
METHYLENE CHLORIDE	9.1E+03	Taste & Odors	6.6E+06	9.1E+03	Ontario MOEE	5.0E+04
METHYL ETHYL KETONE	8.4E+03	Taste & Odors	1.3E+08	8.4E+03	Amoore & Hautala	5.0E+04
METHYL ISOBUTYL KETONE	1.3E+03	Taste & Odors	9.5E+06	1.3E+03	Amoore & Hautala	5.0E+04
METHYL MERCURY	5.0E+04	Upper Limit		-	-	5.0E+04
METHYLNAPHTHALENE (total 1- & 2-)	1.0E+01	Taste & Odors	1.3E+04	1.0E+01	Ontario MOEE	5.0E+04
METHYL TERT BUTYL ETHER	5.0E+00	Taste & Odors	7.5E+07	5.0E+00	Cal DHS 2nd MCL	5.0E+04
MOLYBDENUM	5.0E+04	Upper Limit		-	-	5.0E+04
NAPHTHALENE	2.1E+01	Taste & Odors	1.6E+04	2.1E+01	Amoore & Hautala	5.0E+04
NICKEL	5.0E+04	Upper Limit		-	-	5.0E+04
PENTACHLOROPHENOL	3.0E+01	Taste & Odors	7.0E+06	3.0E+01	Amoore & Hautala	5.0E+04
PERCHLORATE	5.0E+04	Upper Limit	1.0E+08	-	-	5.0E+04
PHENANTHRENE	4.1E+02	Solubility	4.1E+02	1.0E+03	Ontario MOEE	5.0E+04
PHENOL	5.0E+00	Taste & Odors	4.0E+07	5.0E+00	Cal DHS AL	5.0E+04
POLYCHLORINATED BIPHENYLS (PCBs)	1.6E+01	Solubility	1.6E+01	-	-	5.0E+04
PYRENE	6.8E+01	Solubility	6.8E+01	-	-	5.0E+04
SELENIUM	5.0E+04	Upper Limit		-	-	5.0E+04
SILVER	1.0E+02	Taste & Odors		1.0E+02	Cal DHS 2nd MCL	5.0E+04
STYRENE	1.0E+01	Taste & Odors	1.6E+05	1.0E+01	USEPA 2nd MCL	5.0E+04
tert-BUTYL ALCOHOL	5.0E+04	Upper Limit	5.0E+08	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,1,2-	5.0E+04	Upper Limit	1.5E+06	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,2,2-	5.0E+02	Taste & Odors	1.5E+06	5.0E+02	Amoore & Hautala	5.0E+04
TETRACHLOROETHYLENE	1.7E+02	Taste & Odors	1.0E+05	1.7E+02	Amoore & Hautala	5.0E+04
THALLIUM	5.0E+04	Upper Limit		-	-	5.0E+04
TOLUENE	4.0E+01	Taste & Odors	2.6E+05	4.0E+01	USEPA 2nd MCL	5.0E+04
TOXAPHENE	1.4E+02	Taste & Odors	1.5E+03	1.4E+02	USEPA 2nd MCL	5.0E+04
TPH (gasolines)	1.0E+02	Taste & Odors	7.5E+04	1.0E+02	USEPA SNARL	5.0E+04
TPH (middle distillates)	1.0E+02	Taste & Odors	2.5E+03	1.0E+02	USEPA SNARL	5.0E+04
TPH (residual fuels)	1.0E+02	Taste & Odors	2.5E+03	1.0E+02	USEPA SNARL	5.0E+04
TRICHLOROBENZENE, 1,2,4-	3.0E+03	Taste & Odors	1.5E+05	3.0E+03	USEPA (1995)	5.0E+04

TABLE I-1. GROUNDWATER CEILING LEVELS

(groundwater IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
TRICHLOROETHANE, 1,1,1-	9.7E+02	Taste & Odors	6.7E+05	9.7E+02	Amoore & Hautala	5.0E+04
TRICHLOROETHANE, 1,1,2-	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
TRICHLOROETHYLENE	3.1E+02	Taste & Odors	5.5E+05	3.1E+02	Amoore & Hautala	5.0E+04
TRICHLOROPHENOL, 2,4,5-	2.0E+02	Taste & Odors	6.0E+05	2.0E+02	Ontario MOEE	5.0E+04
TRICHLOROPHENOL, 2,4,6-	1.0E+02	Taste & Odors	4.0E+05	1.0E+02	Ontario MOEE	5.0E+04
VANADIUM	5.0E+04	Upper Limit		-	-	5.0E+04
VINYL CHLORIDE	3.4E+03	Taste & Odors	1.4E+06	3.4E+03	Amoore & Hautala	5.0E+04
XYLENES	2.0E+01	Taste & Odors	8.1E+04	2.0E+01	USEPA 2nd MCL	5.0E+04
ZINC	5.0E+03	Taste & Odors		5.0E+03	Cal DHS 2nd MCL	5.0E+04

References:

Unless otherwise noted, criteria for drinking water taste and odor threshhold from summary in *A Compilation of Water Quality Goals* (RWQCBCV 2003) or Ontario MOEE if not available (MOEE 1996).

Upper limit of 50000 ug/L intended to limit general groundwater resource degradation (MOEE 1996).

1/2 solubility based on solubility constants in USEPA Region IX (USEPA 1998) or Ontario MOEE (MOEE 1996) if not available.

Notes:

Ceiling Level: lowest of 1/2 solubility, taste and odor threshhold and 50000 ug/L maximum level

TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

TPH ceiling levels after Massachusetts DEP (MADEP 1997a).

TPH Taste and Odor Thresholds based on USEPA Suggested-No-Adverse-reaction (SNARL) level for TPH diesel.

TABLE I-2. GROUNDWATER GROSS CONTAMINATION CEILING LEVELS
(groundwater IS NOT a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
ACENAPHTHENE	2.0E+02	Nuisance Odors	2.1E+03	2.0E+02	Ontario MOEE	5.0E+04
ACENAPHTHYLENE	2.0E+03	Solubility	2.0E+03	-	-	5.0E+04
ACETONE	5.0E+04	Upper Limit	5.0E+08	200000	Ontario MOEE	5.0E+04
ALDRIN	8.5E+00	Solubility	8.5E+00	170	Ontario MOEE	5.0E+04
ANTHRACENE	2.2E-01	Solubility	2.2E+01	-	-	5.0E+04
ANTIMONY	5.0E+04	Upper Limit		-	-	5.0E+04
ARSENIC	5.0E+04	Upper Limit		-	-	5.0E+04
BARIUM	5.0E+04	Upper Limit		-	-	5.0E+04
BENZENE	2.0E+04	Nuisance Odors	8.8E+05	2.0E+04	Ontario MOEE	5.0E+04
BENZO(a)ANTHRACENE	5.0E+00	Solubility	5.0E+00	-	-	5.0E+04
BENZO(b)FLUORANTHENE	7.0E+00	Solubility	7.0E+00	-	-	5.0E+04
BENZO(k)FLUORANTHENE	4.0E-01	Solubility	4.0E-01	-	-	5.0E+04
BENZO(g,h,i)PERYLENE	1.3E-01	Solubility	1.3E-01	-	-	5.0E+04
BENZO(a)PYRENE	1.9E+00	Solubility	1.9E+00	-	-	5.0E+04
BERYLLIUM	5.0E+04	Upper Limit		-	-	5.0E+04
BIPHENYL, 1,1-	5.0E+00	Nuisance Odors	3.8E+03	5.0E+00	Amoore & Hautala	5.0E+04
BIS(2-CHLOROETHYL)ETHER	3.6E+03	Nuisance Odors	8.6E+06	3.6E+03	Amoore & Hautala	5.0E+04
BIS(2-CHLOROISOPROPYL)ETHER	3.2E+03	Nuisance Odors	8.5E+05	3.2E+03	Ontario MOEE	5.0E+04
BIS(2-ETHYLHEXYL)PHTHALATE	6.5E+02	Solubility	6.5E+02	-	-	5.0E+04
BORON	5.0E+04	Upper Limit	3.4E+06	-	-	5.0E+04
BROMODICHLOROMETHANE	5.0E+04	Upper Limit		-	-	5.0E+04
BROMOFORM	5.1E+03	Nuisance Odors	1.6E+06	5.1E+03	Ontario MOEE	5.0E+04
BROMOMETHANE	5.0E+04	Upper Limit	7.6E+06	-	-	5.0E+04
CADMIUM	5.0E+04	Upper Limit		-	-	5.0E+04
CARBON TETRACHLORIDE	5.2E+03	Nuisance Odors	4.0E+05	5.2E+03	Ontario MOEE	5.0E+04
CHLORDANE	2.5E+01	Nuisance Odors	2.8E+01	2.5E+01	Ontario MOEE	5.0E+04
CHLOROANILINE, p-	5.0E+04	Upper Limit	1.3E+06	-	-	5.0E+04
CHLOROBENZENE	5.0E+02	Nuisance Odors	2.4E+05	5.0E+02	Ontario MOEE	5.0E+04
CHLOROETHANE	1.6E+02	Nuisance Odors	2.9E+06	1.6E+02	Amoore & Hautala	5.0E+04
CHLOROFORM	2.4E+04	Nuisance Odors	4.0E+06	2.4E+04	Ontario MOEE	5.0E+04
CHLOROMETHANE	5.0E+04	Upper Limit	4.1E+06	-	-	5.0E+04
CHLOROPHENOL, 2-	1.8E+00	Nuisance Odors	1.1E+07	1.8E+00	Ontario MOEE	5.0E+04
CHROMIUM (Total)	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM III	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM VI	5.0E+04	Upper Limit		-	-	5.0E+04
CHRYSENE	8.0E-01	Solubility	8.0E-01	-	-	5.0E+04
COBALT	5.0E+04	Upper Limit		-	-	5.0E+04
COPPER	5.0E+04	Upper Limit		-	-	5.0E+04

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
CYANIDE (Free)	1.7E+03	Nuisance Odors	5.0E+08	1.7E+03	Ontario MOEE	5.0E+04
DIBENZO(a,h)ANTHTRACENE	2.5E-01	Solubility	2.5E-01	-	-	5.0E+04
DIBROMOCHLOROMETHANE	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
1,2-DIBROMO-3-CHLOROPROPANE	1.0E+02	Nuisance Odors	6.0E+05	1.0E+02	Amoore & Hautala	5.0E+04
DIBROMOETHANE, 1,2-	5.0E+04	Upper Limit	1.7E+06	-	-	5.0E+04
DICHLOROBENZENE, 1,2-	1.0E+02	Nuisance Odors	7.8E+04	1.0E+02	Ontario MOEE	5.0E+04
DICHLOROBENZENE, 1,3-	5.0E+04	Upper Limit	7.8E+04	-	-	5.0E+04
DICHLOROBENZENE, 1,4-	1.1E+02	Nuisance Odors	3.7E+04	1.1E+02	Ontario MOEE	5.0E+04
DICHLOROBENZIDINE, 3,3-	1.6E+03	Solubility	1.6E+03	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.0E+01	Solubility	8.0E+01	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.0E-01	Solubility	2.0E+01	-	-	5.0E+04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.5E+00	Solubility	1.5E+00	3.5E+03	Ontario MOEE	5.0E+04
DICHLOROETHANE, 1,1-	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DICHLOROETHANE, 1,2-	5.0E+04	Upper Limit	4.3E+06	2.0E+05	Ontario MOEE	5.0E+04
DICHLOROETHYLENE, 1,1-	1.5E+04	Nuisance Odors	1.1E+06	1.5E+04	Amoore & Hautala	5.0E+04
DICHLOROETHYLENE, Cis 1,2-	5.0E+04	Upper Limit	1.8E+06	-	-	5.0E+04
DICHLOROETHYLENE, Trans 1,2-	2.6E+03	Nuisance Odors	3.2E+06	2.6E+03	Ontario MOEE	5.0E+04
DICHLOROPHENOL, 2,4-	3.0E+00	Nuisance Odors	2.3E+06	3.0E+00	Ontario MOEE	5.0E+04
DICHLOROPROPANE, 1,2-	1.0E+02	Nuisance Odors	1.4E+06	1.0E+02	Ontario MOEE	5.0E+04
DICHLOROPROPENE, 1,3-	5.0E+04	Upper Limit	1.4E+06	-	-	5.0E+04
DIELDRIN	9.3E-01	Solubility	9.3E+01	4.1E+02	Ontario MOEE	5.0E+04
DIETHYLPHTHALATE	5.0E+04	Upper Limit	4.5E+05	-	-	5.0E+04
DIMETHYLPHTHALATE	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DIMETHYLPHENOL, 2,4-	4.0E+03	Nuisance Odors	3.9E+06	4.0E+03	Ontario MOEE	5.0E+04
DINITROPHENOL, 2,4-	5.0E+04	Upper Limit	2.8E+06	-	-	5.0E+04
DINITROTOLUENE, 2,4-	5.0E+04	Upper Limit	1.4E+05	-	-	5.0E+04
1,4 DIOXANE	5.0E+04	Upper Limit	5.0E+08	-	-	5.0E+04
DIOXIN (2,3,7,8-TCDD)	7.0E-03	Solubility	7.0E+03	-	-	5.0E+04
ENDOSULFAN	7.5E-01	Solubility	7.5E+01	-	-	5.0E+04
ENDRIN	1.3E-02	Solubility	1.3E+02	4.1E+02	Ontario MOEE	5.0E+04
ETHANOL	5.0E+04	Upper Limit	1.0E+09	7.6E+05	Amoore & Hautala	5.0E+04
ETHYLBENZENE	3.0E+02	Nuisance Odors	8.5E+04	3.0E+02	USEPA 2nd MCL	5.0E+04
FLUORANTHENE	1.3E+02	Solubility	1.3E+02	-	-	5.0E+04
FLUORENE	9.5E+02	Solubility	9.5E+02	-	-	5.0E+04
HEPTACHLOR	2.8E-01	Solubility	2.8E+01	2.0E+02	Ontario MOEE	5.0E+04
HEPTACHLOR EPOXIDE	1.8E-02	Solubility	1.8E+02	-	-	5.0E+04
HEXACHLOROBENZENE	5.5E-01	Solubility	5.5E+01	3.0E+04	Ontario MOEE	5.0E+04
HEXACHLOROBUTADIENE	6.0E-01	Nuisance Odors	1.0E+03	6.0E+01	Ontario MOEE	5.0E+04

TABLE I-2. GROUNDWATER GROSS CONTAMINATION CEILING LEVELS
(groundwater IS NOT a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	3.5E+03	Solubility	3.5E+03	1.2E+05	Ontario MOEE	5.0E+04
HEXACHLOROETHANE	1.0E+02	Nuisance Odors	2.5E+04	1.0E+02	Ontario MOEE	5.0E+04
INDENO(1,2,3-cd)PYRENE	2.7E-01	Solubility	2.7E-01	-	-	5.0E+04
LEAD	5.0E+04	Upper Limit				5.0E+04
MERCURY	5.0E+04	Upper Limit				5.0E+04
METHOXYCHLOR	2.0E+01	Solubility	2.0E+01	4.7E+04	Ontario MOEE	5.0E+04
METHYLENE CHLORIDE	5.0E+04	Upper Limit	6.6E+06	9.1E+04	Ontario MOEE	5.0E+04
METHYL ETHYL KETONE	5.0E+04	Upper Limit	1.3E+08	8.4E+04	Amoore & Hautala	5.0E+04
METHYL ISOBUTYL KETONE	1.3E+04	Nuisance Odors	9.5E+06	1.3E+04	Amoore & Hautala	5.0E+04
METHYL MERCURY	5.0E+04	Upper Limit				5.0E+04
METHYLNAPHTHALENE (total 1- & 2-)	1.0E+02	Nuisance Odors	1.3E+04	1.0E+02	Ontario MOEE	5.0E+04
METHYL TERT BUTYL ETHER	1.8E+03	Nuisance Odors	7.5E+07	1.8E+03	CalDHS	5.0E+04
MOLYBDENUM	5.0E+04	Upper Limit				5.0E+04
NAPHTHALENE	2.1E+02	Nuisance Odors	1.6E+04	2.1E+02	Ontario MOEE	5.0E+04
NICKEL	5.0E+04	Upper Limit				5.0E+04
PENTACHLOROPHENOL	5.9E+03	Nuisance Odors	7.0E+06	5.9E+03	Ontario MOEE	5.0E+04
PERCHLORATE	5.0E+04	Upper Limit	1.0E+08	-	-	5.0E+04
PHENANTHRENE	4.1E+02	Solubility	4.1E+02	1.0E+04	Ontario MOEE	5.0E+04
PHENOL	5.0E+04	Upper Limit	4.0E+07	7.9E+04	Ontario MOEE	5.0E+04
POLYCHLORINATED BIPHENYLS (PCBs)	1.6E+01	Solubility	1.6E+01	-	-	5.0E+04
PYRENE	6.8E+01	Solubility	6.8E+01	-	-	5.0E+04
SELENIUM	5.0E+04	Upper Limit				5.0E+04
SILVER	5.0E+04	Upper Limit				5.0E+04
STYRENE	1.1E+02	Nuisance Odors	1.6E+05	1.1E+02	Ontario MOEE	5.0E+04
tert-BUTYL ALCOHOL	5.0E+04	Upper Limit	5.0E+08	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,1,2-	5.0E+04	Upper Limit	1.5E+06	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,2,2-	5.0E+03	Nuisance Odors	1.5E+06	5.0E+03	Ontario MOEE	5.0E+04
TETRACHLOROETHYLENE	3.0E+03	Nuisance Odors	1.0E+05	3.0E+03	Ontario MOEE	5.0E+04
THALLIUM	5.0E+04	Upper Limit				5.0E+04
TOLUENE	4.0E+02	Nuisance Odors	2.6E+05	4.0E+02	Ontario MOEE	5.0E+04
TOXAPHENE	1.4E+02	Nuisance Odors	1.5E+03	1.4E+02	USEPA 2nd MCL	5.0E+04
TPH (gasolines)	5.0E+03	Nuisance Odors	7.5E+04	5.0E+03	MADEP	5.0E+04
TPH (middle distillates)	2.5E+03	Solubility	2.5E+03	5.0E+03	MADEP	5.0E+04
TPH (residual fuels)	2.5E+03	Solubility	2.5E+03	5.0E+03	MADEP	5.0E+04
TRICHLOROBENZENE, 1,2,4-	3.0E+04	Nuisance Odors	1.5E+05	3.0E+04	USEPA (1995)	5.0E+04
TRICHLOROETHANE, 1,1,1-	5.0E+04	Upper Limit	6.7E+05	5.0E+05	Ontario MOEE	5.0E+04
TRICHLOROETHANE, 1,1,2-	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
TRICHLOROETHYLENE	5.0E+04	Upper Limit	5.5E+05	1.0E+05	Ontario MOEE	5.0E+04

TABLE I-2. GROUNDWATER GROSS CONTAMINATION CEILING LEVELS
(groundwater IS NOT a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
TRICHLOROPHENOL, 2,4,5-	2.0E+03	Nuisance Odors	6.0E+05	2.0E+03	Ontario MOEE	5.0E+04
TRICHLOROPHENOL, 2,4,6-	1.0E+03	Nuisance Odors	4.0E+05	1.0E+03	Ontario MOEE	5.0E+04
VANADIUM	5.0E+04	Upper Limit	-	-	-	5.0E+04
VINYL CHLORIDE	3.4E+04	Nuisance Odors	1.4E+06	3.4E+04	Ontario MOEE	5.0E+04
XYLENES	5.3E+03	Nuisance Odors	8.1E+04	5.3E+03	Ontario MOEE	5.0E+04
ZINC	5.0E+04	Upper Limit	-	-	-	5.0E+04

References:

Unless otherwise noted, criteria for nuisance odor threshold from Ontario MOEE (MOEE 1996) OR data from Amoore and Hautala (1983) as presented in *A Compilation of Water Quality Goals* if not available *(RWQCBCV 2003)*.

Upper limit of 50000 ug/L intended to limit general groundwater resource degradation (MOEE 1996).

1/2 solubility based on solubility constants in USEPA Region IX (USEPA 2004) or Ontario MOEE (MOEE 1996) if not available.

Odor threshold for MTBE based on average, upper range at which most subjects could smell MTBE in water (CalEPA 1999).

Vapor Pressure for ethanol from *Fate and Transport of Ethanol-Blended Gasoline in the Environment* (Ulrich 1999). Odor threshold from

Notes:

Nuisance Odor Thresholds assume ten-fold attenuation/dilution of chemical in groundwater upon discharge to surface water.

Ceiling Level: lowest of 1/2 solubility, odor/taste threshold and 50000 ug/L maximum level (intended to limit general groundwater resource degradation).

TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.

TPH ceiling level after Massachusetts DEP (MADEP 1997a).

TABLE I-3. SURFACE WATER CEILING LEVELS
(surface water IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
ACENAPHTHENE	2.0E+01	Taste & Odors	2.1E+03	2.0E+01	Ontario MOEE	5.0E+04
ACENAPHTHYLENE	2.0E+03	Solubility	2.0E+03	-	-	5.0E+04
ACETONE	2.0E+04	Taste & Odors	5.0E+08	2.0E+04	Amoore & Hautala	5.0E+04
ALDRIN	8.5E+00	Solubility	8.5E+00	1.7E+01	Ontario MOEE	5.0E+04
ANTHRACENE	2.2E+01	Solubility	2.2E+01	-	-	5.0E+04
ANTIMONY	5.0E+04	Upper Limit		-	-	5.0E+04
ARSENIC	5.0E+04	Upper Limit		-	-	5.0E+04
BARIUM	5.0E+04	Upper Limit				5.0E+04
BENZENE	1.7E+02	Taste & Odors	8.8E+05	1.7E+02	Amoore & Hautala	5.0E+04
BENZO(a)ANTHRACENE	5.0E+00	Solubility	5.0E+00	-	-	5.0E+04
BENZO(b)FLUORANTHENE	7.0E+00	Solubility	7.0E+00	-	-	5.0E+04
BENZO(k)FLUORANTHENE	4.0E-01	Solubility	4.0E-01	-	-	5.0E+04
BENZO(g,h,i)PERYLENE	1.3E-01	Solubility	1.3E-01	-	-	5.0E+04
BENZO(a)PYRENE	1.9E+00	Solubility	1.9E+00	-	-	5.0E+04
BERYLLIUM	5.0E+04	Upper Limit		-	-	5.0E+04
BIPHENYL, 1,1-	5.0E-01	Taste & Odors	3.8E+03	5.0E-01	Amoore & Hautala	5.0E+04
BIS(2-CHLOROETHYL)ETHER	3.6E+02	Taste & Odors	8.6E+06	3.6E+02	Amoore & Hautala	5.0E+04
BIS(2-CHLOROISOPROPYL)ETHER	3.2E+02	Taste & Odors	8.5E+05	3.2E+02	Ontario MOEE	5.0E+04
BIS(2-ETHYLHEXYL)PHTHALATE	6.5E+02	Solubility	6.5E+02	-	-	5.0E+04
BORON	5.0E+04	Upper Limit		-	-	5.0E+04
BROMODICHLOROMETHANE	5.0E+04	Upper Limit	3.4E+06	-	-	5.0E+04
BROMOFORM	5.1E+02	Taste & Odors	1.6E+06	5.1E+02	Amoore & Hautala	5.0E+04
BROMOMETHANE	5.0E+04	Upper Limit	7.6E+06	-	-	5.0E+04
CADMIUM	5.0E+04	Upper Limit		-	-	5.0E+04
CARBON TETRACHLORIDE	5.2E+02	Taste & Odors	4.0E+05	5.2E+02	Amoore & Hautala	5.0E+04
CHLORDANE	2.5E+00	Taste & Odors	2.8E+01	2.5E+00	Ontario MOEE	5.0E+04
CHLOROANILINE, p-	5.0E+04	Upper Limit	1.3E+06	-	-	5.0E+04
CHLOROBENZENE	5.0E+01	Taste & Odors	2.4E+05	5.0E+01	Amoore & Hautala	5.0E+04
CHLOROETHANE	1.6E+01	Taste & Odors	2.9E+06	1.6E+01	Amoore & Hautala	5.0E+04
CHLOROFORM	2.4E+03	Taste & Odors	4.0E+06	2.4E+03	Amoore & Hautala	5.0E+04
CHLOROMETHANE	5.0E+04	Upper Limit	4.1E+06	-	-	5.0E+04
CHLOROPHENOL, 2-	1.8E-01	Taste & Odors	1.1E+07	1.8E-01	Ontario MOEE	5.0E+04
CHROMIUM (Total)	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM III	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM VI	5.0E+04	Upper Limit		-	-	5.0E+04
CHRYSENE	8.0E-01	Solubility	8.0E-01	-	-	5.0E+04
COBALT	5.0E+04	Upper Limit		-	-	5.0E+04

TABLE I-3. SURFACE WATER CEILING LEVELS
(surface water IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
COPPER	1.0E+03	Taste & Odors		1.0E+03	CalDHS 2nd MCL	5.0E+04
CYANIDE (Free)	1.7E+02	Taste & Odors	5.0E+08	1.7E+02	Amoore & Hautala	5.0E+04
DIBENZO(a,h)ANTHTRACENE	2.5E-01	Solubility	2.5E-01	-	-	5.0E+04
DIBROMOCHLOROMETHANE	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
1,2-DIBROMO-3-CHLOROPROPANE	1.0E+01	Taste & Odors	6.0E+05	1.0E+01	Amoore & Hautala	5.0E+04
DIBROMOETHANE, 1,2-	5.0E+04	Upper Limit	1.7E+06	-	-	5.0E+04
DICHLOROBENZENE, 1,2-	1.0E+01	Taste & Odors	7.8E+04	1.0E+01	USEPA 2nd MCL	5.0E+04
DICHLOROBENZENE, 1,3-	5.0E+04	Upper Limit	7.8E+04	-	-	5.0E+04
DICHLOROBENZENE, 1,4-	5.0E+00	Taste & Odors	3.7E+04	5.0E+00	USEPA 2nd MCL	5.0E+04
DICHLOROBENZIDINE, 3,3-	1.6E+03	Solubility	1.6E+03	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.0E+01	Solubility	8.0E+01	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.0E+01	Solubility	2.0E+01	-	-	5.0E+04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.5E+00	Solubility	1.5E+00	3.5E+02	Ontario MOEE	5.0E+04
DICHLOROETHANE, 1,1-	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DICHLOROETHANE, 1,2-	7.0E+03	Taste & Odors	4.3E+06	7.0E+03	Amoore & Hautala	5.0E+04
DICHLOROETHYLENE, 1,1-	1.5E+03	Taste & Odors	1.1E+06	1.5E+03	Amoore & Hautala	5.0E+04
DICHLOROETHYLENE, Cis 1,2-	5.0E+04	Upper Limit	1.8E+06	-	-	5.0E+04
DICHLOROETHYLENE, Trans 1,2-	2.6E+02	Taste & Odors	3.2E+06	2.6E+02	Amoore & Hautala	5.0E+04
DICHLOROPHENOL, 2,4-	3.0E-01	Taste & Odors	2.3E+06	3.0E-01	Ontario MOEE	5.0E+04
DICHLOROPROPANE, 1,2-	1.0E+01	Taste & Odors	1.4E+06	1.0E+01	Ontario MOEE	5.0E+04
DICHLOROPROPENE, 1,3-	5.0E+04	Upper Limit	1.4E+06	-	-	5.0E+04
DIELDRIN	4.1E+01	Taste & Odors	9.3E+01	4.1E+01	Ontario MOEE	5.0E+04
DIETHYLPHTHALATE	5.0E+04	Upper Limit	4.5E+05	-	-	5.0E+04
DIMETHYLPHTHALATE	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DIMETHYLPHENOL, 2,4-	4.0E+02	Taste & Odors	3.9E+06	4.0E+02	Cal DHS AL	5.0E+04
DINITROPHENOL, 2,4-	5.0E+04	Upper Limit	2.8E+06	-	-	5.0E+04
DINITROTOLUENE, 2,4-	5.0E+04	Upper Limit	1.4E+05	-	-	5.0E+04
1,4 DIOXANE	5.0E+04	Upper Limit	5.0E+08	2.3E+05	Amoore & Hautala	5.0E+04
DIOXIN (2,3,7,8-TCDD)	7.0E+03	Solubility	7.0E+03	-	-	5.0E+04
ENDOSULFAN	7.5E+01	Solubility	7.5E+01	-	-	5.0E+04
ENDRIN	4.1E+01	Taste & Odors	1.3E+02	4.1E+01	Ontario MOEE	5.0E+04
ETHANOL	5.0E+04	Upper Limit	1.0E+09	7.6E+05	Amoore & Hautala	5.0E+04
ETHYLBENZENE	3.0E+01	Taste & Odors	8.5E+04	3.0E+01	USEPA 2nd MCL	5.0E+04
FLUORANTHENE	1.3E+02	Solubility	1.3E+02	-	-	5.0E+04
FLUORENE	9.5E+02	Solubility	9.5E+02	-	-	5.0E+04
HEPTACHLOR	2.0E+01	Taste & Odors	2.8E+01	2.0E+01	Ontario MOEE	5.0E+04
HEPTACHLOR EPOXIDE	1.8E+02	Solubility	1.8E+02	-	-	5.0E+04

TABLE I-3. SURFACE WATER CEILING LEVELS
(surface water IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
HEXACHLOROBENZENE	5.5E+01	Solubility	5.5E+01	3.0E+03	Ontario MOEE	5.0E+04
HEXACHLOROBUTADIENE	6.0E+00	Taste & Odors	1.0E+03	6.0E+00	Ontario MOEE	5.0E+04
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	3.5E+03	Solubility	3.5E+03	1.2E+04	Ontario MOEE	5.0E+04
HEXACHLOROETHANE	1.0E+01	Taste & Odors	2.5E+04	1.0E+01	Amoore & Hautala	5.0E+04
INDENO(1,2,3-cd)PYRENE	2.7E-01	Solubility	2.7E-01	-	-	5.0E+04
LEAD	5.0E+04	Upper Limit		-	-	5.0E+04
MERCURY	5.0E+04	Upper Limit		-	-	5.0E+04
METHOXYCHLOR	2.0E-01	Solubility	2.0E-01	4.7E+03	Amoore & Hautala	5.0E+04
METHYLENE CHLORIDE	9.1E+03	Taste & Odors	6.6E+06	9.1E+03	Ontario MOEE	5.0E+04
METHYL ETHYL KETONE	8.4E+03	Taste & Odors	1.3E+08	8.4E+03	Amoore & Hautala	5.0E+04
METHYL ISOBUTYL KETONE	1.3E+03	Taste & Odors	9.5E+06	1.3E+03	Amoore & Hautala	5.0E+04
METHYL MERCURY	5.0E+04	Upper Limit		-	-	5.0E+04
METHYLNAPHTHALENE (total 1- & 2-)	1.0E+01	Taste & Odors	1.3E+04	1.0E+01	Ontario MOEE	5.0E+04
METHYL TERT BUTYL ETHER	5.0E+00	Taste & Odors	7.5E+07	5.0E+00	Cal DHS 2nd MCL	5.0E+04
MOLYBDENUM	5.0E+04	Upper Limit		-	-	5.0E+04
NAPHTHALENE	2.1E+01	Taste & Odors	1.6E+04	2.1E+01	Amoore & Hautala	5.0E+04
NICKEL	5.0E+04	Upper Limit		-	-	5.0E+04
PENTACHLOROPHENOL	3.0E+01	Taste & Odors	7.0E+06	3.0E+01	Amoore & Hautala	5.0E+04
PERCHLORATE	5.0E+04	Upper Limit	1.0E+08	-	-	5.0E+04
PHENANTHRENE	4.1E+02	Solubility	4.1E+02	1.0E+03	Ontario MOEE	5.0E+04
PHENOL	5.0E+00	Taste & Odors	4.0E+07	5.0E+00	Cal DHS AL	5.0E+04
POLYCHLORINATED BIPHENYLS (PCBs)	1.6E+01	Solubility	1.6E+01	-	-	5.0E+04
PYRENE	6.8E+01	Solubility	6.8E+01	-	-	5.0E+04
SELENIUM	5.0E+04	Upper Limit		-	-	5.0E+04
SILVER	1.0E+02	Taste & Odors		1.0E+02	Cal DHS 2nd MCL	5.0E+04
STYRENE	1.0E+01	Taste & Odors	1.6E+05	1.0E+01	USEPA 2nd MCL	5.0E+04
tert-BUTYL ALCOHOL	5.0E+04	Upper Limit	5.0E+08	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,1,2-	5.0E+04	Upper Limit	1.5E+06	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,2,2-	5.0E+02	Taste & Odors	1.5E+06	5.0E+02	Amoore & Hautala	5.0E+04
TETRACHLOROETHYLENE	1.7E+02	Taste & Odors	1.0E+05	1.7E+02	Amoore & Hautala	5.0E+04
THALLIUM	5.0E+04	Upper Limit		-	-	5.0E+04
TOLUENE	4.0E+01	Taste & Odors	2.6E+05	4.0E+01	USEPA 2nd MCL	5.0E+04
TOXAPHENE	1.4E+02	Taste & Odors	1.5E+03	1.4E+02	USEPA 2nd MCL	5.0E+04
TPH (gasolines)	1.0E+02	Taste & Odors	7.5E+04	1.0E+02	USEPA SNARL	5.0E+04
TPH (middle distillates)	1.0E+02	Taste & Odors	2.5E+03	1.0E+02	USEPA SNARL	5.0E+04
TPH (residual fuels)	1.0E+02	Taste & Odors	2.5E+03	1.0E+02	USEPA SNARL	5.0E+04
TRICHLOROBENZENE, 1,2,4-	3.0E+03	Taste & Odors	1.5E+05	3.0E+03	USEPA (1995)	5.0E+04

TABLE I-3. SURFACE WATER CEILING LEVELS
(surface water IS a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Ceiling Level	Basis	Solubility (1/2)	Taste And Odor Threshold	Basis	Upper Limit
TRICHLOROETHANE, 1,1,1-	9.7E+02	Taste & Odors	6.7E+05	9.7E+02	Amoore & Hautala	5.0E+04
TRICHLOROETHANE, 1,1,2-	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
TRICHLOROETHYLENE	3.1E+02	Taste & Odors	5.5E+05	3.1E+02	Amoore & Hautala	5.0E+04
TRICHLOROPHENOL, 2,4,5-	2.0E+02	Taste & Odors	6.0E+05	2.0E+02	Ontario MOEE	5.0E+04
TRICHLOROPHENOL, 2,4,6-	1.0E+02	Taste & Odors	4.0E+05	1.0E+02	Ontario MOEE	5.0E+04
VANADIUM	5.0E+04	Upper Limit		-	-	5.0E+04
VINYL CHLORIDE	3.4E+03	Taste & Odors	1.4E+06	3.4E+03	Amoore & Hautala	5.0E+04
XYLENES	2.0E+01	Taste & Odors	8.1E+04	2.0E+01	USEPA 2nd MCL	5.0E+04
ZINC	5.0E+03	Taste & Odors		5.0E+03	Cal DHS 2nd MCL	5.0E+04

References:
Unless otherwise noted, criteria for drinking water taste and odor threshold from summary in *A Compilation of Water Quality Goals* (RWQCBCV 2003) or Ontario MOEE if not available (MOEE 1996).
Upper limit of 50000 ug/L intended to limit general groundwater resource degradation (MOEE 1996).
1/2 solubility based on solubility constants in USEPA Region IX (USEPA 2004) or Ontario MOEE (MOEE 1996) if not available.

Notes:
Ceiling Level: lowest of 1/2 solubility, taste and odor threshhold and 50000 ug/L maximum level
TPH -Total Petroleum Hydrocarbons. See text for discussion of different TPH categories.
TPH ceiling levels after Massachusetts DEP (MADEP 1997a).
TPH Taste and Odor Thresholds based on USEPA Suggested-No-Adverse-reaction (SNARL) level for TPH diesel.

TABLE I-4. SURFACE WATER GROSS CONTAMINATION CEILING LEVELS
(surface water IS NOT a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
ACENAPHTHENE	2.0E-01	Nuisance Odors	2.1E+03	2.0E-01	Ontario MOEE	5.0E+04
ACENAPHTHYLENE	2.0E-03	Solubility	2.0E+03	-	-	5.0E+04
ACETONE	2.0E+04	Nuisance Odors	5.0E+08	2.0E+04	Ontario MOEE	5.0E+04
ALDRIN	8.5E+00	Solubility	8.5E+00	1.7E-01	Ontario MOEE	5.0E+04
ANTHRACENE	2.2E-01	Solubility	2.2E+01	-	-	5.0E+04
ANTIMONY	5.0E+04	Upper Limit		-	-	5.0E+04
ARSENIC	5.0E+04	Upper Limit		-	-	5.0E+04
BARIUM	5.0E+04	Upper Limit		-	-	5.0E+04
BENZENE	2.0E+03	Nuisance Odors	8.8E+05	2.0E+03	Ontario MOEE	5.0E+04
BENZO(a)ANTHRACENE	5.0E+00	Solubility	5.0E+00	-	-	5.0E+04
BENZO(b)FLUORANTHENE	7.0E+00	Solubility	7.0E+00	-	-	5.0E+04
BENZO(k)FLUORANTHENE	4.0E-01	Solubility	4.0E-01	-	-	5.0E+04
BENZO(g,h,i)PERYLENE	1.3E-01	Solubility	1.3E-01	-	-	5.0E+04
BENZO(a)PYRENE	1.9E+00	Solubility	1.9E+00	-	-	5.0E+04
BERYLLIUM	5.0E+04	Upper Limit		-	-	5.0E+04
BIPHENYL, 1,1-	5.0E-01	Nuisance Odors	3.8E+03	5.0E-01	Amoore & Hautala	5.0E+04
BIS(2-CHLOROETHYL)ETHER	3.6E+02	Nuisance Odors	8.6E+06	3.6E+02	Amoore & Hautala	5.0E+04
BIS(2-CHLOROISOPROPYL)ETHER	3.2E+02	Nuisance Odors	8.5E+05	3.2E+02	Ontario MOEE	5.0E+04
BIS(2-ETHYLHEXYL)PHTHALATE	6.5E+02	Solubility	6.5E+02	-	-	5.0E+04
BORON	5.0E+04	Upper Limit		-	-	5.0E+04
BROMODICHLOROMETHANE	5.0E+04	Upper Limit	3.4E+06	-	-	5.0E+04
BROMOFORM	5.1E+02	Nuisance Odors	1.6E+06	5.1E+02	Ontario MOEE	5.0E+04
BROMOMETHANE	5.0E+04	Upper Limit	7.6E+06	-	-	5.0E+04
CADMIUM	5.0E+04	Upper Limit		-	-	5.0E+04
CARBON TETRACHLORIDE	5.2E+02	Nuisance Odors	4.0E+05	5.2E+02	Ontario MOEE	5.0E+04
CHLORDANE	2.5E+00	Nuisance Odors	2.8E+01	2.5E+00	Ontario MOEE	5.0E+04
CHLOROANILINE, p-	5.0E+04	Upper Limit	1.3E+06	-	-	5.0E+04
CHLOROBENZENE	5.0E-01	Nuisance Odors	2.4E+05	5.0E-01	Ontario MOEE	5.0E+04
CHLOROETHANE	1.6E-01	Nuisance Odors	2.9E+06	1.6E-01	Amoore & Hautala	5.0E+04
CHLOROFORM	2.4E+03	Nuisance Odors	4.0E+06	2.4E+03	Ontario MOEE	5.0E+04
CHLOROMETHANE	5.0E+04	Upper Limit	4.1E+06	-	-	5.0E+04
CHLOROPHENOL, 2-	1.8E-01	Nuisance Odors	1.1E+07	1.8E-01	Ontario MOEE	5.0E+04
CHROMIUM (Total)	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM III	5.0E+04	Upper Limit		-	-	5.0E+04
CHROMIUM VI	5.0E+04	Upper Limit		-	-	5.0E+04
CHRYSENE	8.0E-01	Solubility	8.0E-01	-	-	5.0E+04
COBALT	5.0E+04	Upper Limit		-	-	5.0E+04
COPPER	5.0E+04	Upper Limit		-	-	5.0E+04

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
CYANIDE (Free)	1.7E+02	Nuisance Odors	5.0E+08	1.7E+02	Ontario MOEE	5.0E+04
DIBENZO(a,h)ANTHTRACENE	2.5E-01	Solubility	2.5E-01	-	-	5.0E+04
DIBROMOCHLOROMETHANE	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
1,2-DIBROMO-3-CHLOROPROPANE	1.0E+01	Nuisance Odors	6.0E+05	1.0E+01	Amoore & Hautala	5.0E+04
DIBROMOETHANE, 1,2-	5.0E+04	Upper Limit	1.7E+06	-	-	5.0E+04
DICHLOROBENZENE, 1,2-	1.0E+01	Nuisance Odors	7.8E+04	1.0E+01	Ontario MOEE	5.0E+04
DICHLOROBENZENE, 1,3-	5.0E+04	Upper Limit	7.8E+04	-	-	5.0E+04
DICHLOROBENZENE, 1,4-	1.1E+01	Nuisance Odors	3.7E+04	1.1E+01	Ontario MOEE	5.0E+04
DICHLOROBENZIDINE, 3,3-	1.6E+03	Solubility	1.6E+03	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHANE (DDD)	8.0E+01	Solubility	8.0E+01	-	-	5.0E+04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.0E+01	Solubility	2.0E+01	-	-	5.0E+04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.5E+00	Solubility	1.5E+00	3.5E+02	Ontario MOEE	5.0E+04
DICHLOROETHANE, 1,1-	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DICHLOROETHANE, 1,2-	2.0E+04	Nuisance Odors	4.3E+06	2.0E+04	Ontario MOEE	5.0E+04
DICHLOROETHYLENE, 1,1-	1.5E+03	Nuisance Odors	1.1E+06	1.5E+03	Amoore & Hautala	5.0E+04
DICHLOROETHYLENE, Cis 1,2-	5.0E+04	Upper Limit	1.8E+06	-	-	5.0E+04
DICHLOROETHYLENE, Trans 1,2-	2.6E+02	Nuisance Odors	3.2E+06	2.6E+02	Ontario MOEE	5.0E+04
DICHLOROPHENOL, 2,4-	3.0E-01	Nuisance Odors	2.3E+06	3.0E-01	Ontario MOEE	5.0E+04
DICHLOROPROPANE, 1,2-	1.0E+01	Nuisance Odors	1.4E+06	1.0E+01	Ontario MOEE	5.0E+04
DICHLOROPROPENE, 1,3-	5.0E+04	Upper Limit	1.4E+06	-	-	5.0E+04
DIELDRIN	4.1E+01	Nuisance Odors	9.3E+01	4.1E+01	Ontario MOEE	5.0E+04
DIETHYLPHTHALATE	5.0E+04	Upper Limit	4.5E+05	-	-	5.0E+04
DIMETHYLPHTHALATE	5.0E+04	Upper Limit	2.5E+06	-	-	5.0E+04
DIMETHYLPHENOL, 2,4-	4.0E+02	Nuisance Odors	3.9E+06	4.0E+02	Ontario MOEE	5.0E+04
DINITROPHENOL, 2,4-	5.0E+04	Upper Limit	2.8E+06	-	-	5.0E+04
DINITROTOLUENE, 2,4-	5.0E+04	Upper Limit	1.4E+05	-	-	5.0E+04
1,4 DIOXANE	5.0E+04	Upper Limit	5.0E+08	-	-	5.0E+04
DIOXIN (2,3,7,8-TCDD)	7.0E+03	Solubility	7.0E+03	-	-	5.0E+04
ENDOSULFAN	7.5E+01	Solubility	7.5E+01	-	-	5.0E+04
ENDRIN	4.1E+01	Nuisance Odors	1.3E+02	4.1E+01	Ontario MOEE	5.0E+04
ETHANOL	5.0E+04	Upper Limit	5.0E+08	7.6E+05	Amoore & Hautala	5.0E+04
ETHYLBENZENE	3.0E+01	Nuisance Odors	8.5E+04	3.0E+01	USEPA 2nd MCL	5.0E+04
FLUORANTHENE	1.3E+02	Solubility	1.3E+02	-	-	5.0E+04
FLUORENE	9.5E+02	Solubility	9.5E+02	-	-	5.0E+04
HEPTACHLOR	2.0E+01	Nuisance Odors	2.8E+01	2.0E+01	Ontario MOEE	5.0E+04
HEPTACHLOR EPOXIDE	1.8E+02	Solubility	1.8E+02	-	-	5.0E+04
HEXACHLOROBENZENE	5.5E+01	Solubility	5.5E+01	3.0E+03	Ontario MOEE	5.0E+04
HEXACHLOROBUTADIENE	6.0E+00	Nuisance Odors	1.0E+03	6.0E+00	Ontario MOEE	5.0E+04

TABLE I-4. SURFACE WATER GROSS CONTAMINATION CEILING LEVELS
(surface water IS NOT a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	3.5E+03	Solubility	3.5E+03	1.2E+04	Ontario MOEE	5.0E+04
HEXACHLOROETHANE	1.0E+01	Nuisance Odors	2.5E+04	1.0E+01	Ontario MOEE	5.0E+04
INDENO(1,2,3-cd)PYRENE	2.7E-01	Solubility	2.7E-01	-	-	5.0E+04
LEAD	5.0E+04	Upper Limit		-	-	5.0E+04
MERCURY	5.0E+04	Upper Limit		-	-	5.0E+04
METHOXYCHLOR	2.0E+01	Solubility	2.0E+01	4.7E+03	Ontario MOEE	5.0E+04
METHYLENE CHLORIDE	9.1E+03	Nuisance Odors	6.6E+06	9.1E+03	Ontario MOEE	5.0E+04
METHYL ETHYL KETONE	8.4E+03	Nuisance Odors	1.3E+08	8.4E+03	Amoore & Hautala	5.0E+04
METHYL ISOBUTYL KETONE	1.3E+03	Nuisance Odors	9.5E+06	1.3E+03	Amoore & Hautala	5.0E+04
METHYL MERCURY	5.0E+04	Upper Limit		-	-	5.0E+04
METHYLNAPHTHALENE (total 1- & 2-)	1.0E+01	Nuisance Odors	1.3E+04	1.0E+01	Ontario MOEE	5.0E+04
METHYL TERT BUTYL ETHER	1.8E+02	Nuisance Odors	7.5E+07	1.8E+02	CalDHS	5.0E+04
MOLYBDENUM	5.0E+04	Upper Limit		-	-	5.0E+04
NAPHTHALENE	2.1E+01	Nuisance Odors	1.6E+04	2.1E+01	Ontario MOEE	5.0E+04
NICKEL	5.0E+04	Upper Limit		-	-	5.0E+04
PENTACHLOROPHENOL	5.9E+02	Nuisance Odors	7.0E+06	5.9E+02	Ontario MOEE	5.0E+04
PERCHLORATE	5.0E+04	Upper Limit	1.0E+08	-	-	5.0E+04
PHENANTHRENE	4.1E+02	Solubility	4.1E+02	1.0E+03	Ontario MOEE	5.0E+04
PHENOL	7.9E+03	Nuisance Odors	4.0E+07	7.9E+03	Ontario MOEE	5.0E+04
POLYCHLORINATED BIPHENYLS (PCBs)	1.6E-01	Solubility	1.6E-01	-	-	5.0E+04
PYRENE	6.8E-01	Solubility	6.8E+01	-	-	5.0E+04
SELENIUM	5.0E+04	Upper Limit		-	-	5.0E+04
SILVER	5.0E+04	Upper Limit		-	-	5.0E+04
STYRENE	1.1E-01	Nuisance Odors	1.6E+05	1.1E+01	Ontario MOEE	5.0E+04
tert-BUTYL ALCOHOL	5.0E+04	Upper Limit	5.0E+08	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,1,2-	5.0E+04	Upper Limit	1.5E+06	-	-	5.0E+04
TETRACHLOROETHANE, 1,1,2,2-	5.0E+02	Nuisance Odors	1.5E+06	5.0E+02	Ontario MOEE	5.0E+04
TETRACHLOROETHYLENE	3.0E+02	Nuisance Odors	1.0E+05	3.0E+02	Ontario MOEE	5.0E+04
THALLIUM	5.0E+04	Upper Limit		-	-	5.0E+04
TOLUENE	4.0E-01	Nuisance Odors	2.6E+05	4.0E+01	Ontario MOEE	5.0E+04
TOXAPHENE	1.4E+02	Nuisance Odors	1.5E+03	1.4E+02	USEPA 2nd MCL	5.0E+04
TPH (gasolines)	5.0E+03	Nuisance Odors	7.5E+04	5.0E+03	MADEP	5.0E+04
TPH (middle distillates)	2.5E+03	Solubility	2.5E+03	5.0E+03	MADEP	5.0E+04
TPH (residual fuels)	2.5E+03	Solubility	2.5E+03	5.0E+03	MADEP	5.0E+04
TRICHLOROBENZENE, 1,2,4-	3.0E+03	Nuisance Odors	1.5E+05	3.0E+03	USEPA (1995)	5.0E+04
TRICHLOROETHANE, 1,1,1-	5.0E+04	Nuisance Odors	6.7E+05	5.0E+04	Ontario MOEE	5.0E+04
TRICHLOROETHANE, 1,1,2-	5.0E+04	Upper Limit	2.2E+06	-	-	5.0E+04
TRICHLOROETHYLENE	1.0E+04	Nuisance Odors	5.5E+05	1.0E+04	Ontario MOEE	5.0E+04

TABLE I-4. SURFACE WATER GROSS CONTAMINATION CEILING LEVELS
(surface water IS NOT a current or potential source of drinking water)
(ug/L)

CHEMICAL PARAMETER	Final Gross Contamination Ceiling Level	Basis	Solubility (1/2)	Nuisance Odor Threshold	Basis	Upper Limit
TRICHLOROPHENOL, 2,4,5-	2.0E+02	Nuisance Odors	6.0E+05	2.0E+02	Ontario MOEE	5.0E+04
TRICHLOROPHENOL, 2,4,6-	1.0E+02	Nuisance Odors	4.0E+05	1.0E+02	Ontario MOEE	5.0E+04
VANADIUM	5.0E+04	Upper Limit	-	-	-	5.0E+04
VINYL CHLORIDE	3.4E+03	Nuisance Odors	1.4E+06	3.4E+03	Ontario MOEE	5.0E+04
XYLENES	5.3E+02	Nuisance Odors	8.1E+04	5.3E+02	Ontario MOEE	5.0E+04
ZINC	5.0E+04	Upper Limit	-	-	-	5.0E+04

References:

Unless otherwise noted, criteria for nuisance odor threshold from Ontario MOEE (MOEE 1996, minus groundwater-to-surface water dilution factor) OR data from Amoore and Hautala (1983) as presented in *A Compilation of Water Quality Goals* if not available (RWQCBCV 2003).

Upper limit of 50000 ug/L intended to limit general groundwater resource degradation (MOEE 1996).

1/2 solubility based on solubility constants in USEPA Region IX (USEPA 2004) or Ontario MOEE (MOEE 1996) if not available.

Odor threshold for MTBE based on average, upper range at which most subjects could smell MTBE in water (CalEPA 1999).

Notes:

Nuisance Odor Thresholds assume no attenuation/dilution of chemical in surface water.

Ceiling Level: lowest of 1/2 solubility, odor/taste threshold and 50000 ug/L maximum level (intended to limit general groundwater resource degradation).

TPH -Total Petroleum Hydrocarbons.   See text for discussion of different TPH categories.

TPH ceiling level after Massachusetts DEP (MADEP 1997a).

TABLE J. PHYSIO-CHEMICAL AND TOXICITY CONSTANTS USED IN MODELS.

Chemical Parameter	Physical State		Molecular Weight	Organic carbon partition coefficient, K_{oc} (cm³/g)	Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Pure component water solubility, S (mg/L)	Henry's Law constant H (atm-m³/mol)	Henry's Law constant H' (unitless)	Skin Absorption Factor ABS (unitless)	Cancer Slope Factor Oral CSFo (mg/kg-d)$^{-1}$	Cancer Slope Factor Inhaled CSFI (mg/kg-d)$^{-1}$	Reference Dose Oral RfDo (mg/kg-d)	Reference Dose Inhaled RfDi (mg/kg-d)
ACENAPHTHENE	V	S	154	4.90E+03	4.21E-02	7.69E-06	4.24E+00	1.55E-04	6.36E-03	0.10			6.00E-02	6.00E-02
ACENAPHTHYLENE	V	S	152	2.50E+03			3.93E+00	1.45E-03	5.95E-02	0.10			4.00E-02	4.00E-02
ACETONE	V	L	58	5.75E-01	1.24E-01	1.14E-05	1.00E+06	3.88E-05	1.59E-03	0.10			9.00E-01	9.00E-01
*ALDRIN	NV	S	365	4.90E+04			1.70E-02	4.96E-05	2.03E-03	0.05	1.70E+01	1.70E+01	3.00E-05	3.00E-05
ANTHRACENE	V	S	178	2.35E+04	3.24E-02	7.74E-06	4.34E-02	6.50E-05	2.67E-03	0.10			3.00E-01	3.00E-01
ANTIMONY	NV	S	122							0.01			4.00E-04	
*ARSENIC	NV	S	75							0.04	9.45E+00	1.20E+01	3.00E-04	8.57E-06
BARIUM	NV	S	137							0.01			7.00E-02	1.43E-04
*BENZENE	V	L	78	5.90E+01	8.80E-02	9.80E-06	1.75E+03	5.56E-03	2.28E-01	0.10	1.00E-01	1.00E-01	3.00E-03	1.70E-02
*BENZO(a)ANTHRACENE	NV	S	228	2.00E+05			1.00E-02	1.00E-06	4.10E-05	0.13	1.20E+00	3.90E-01		
*BENZO(b)FLUORANTHENE	NV	S	252	5.50E+05			1.40E-02	1.22E-05	5.00E-04	0.13	1.20E+00	3.90E-01		
*BENZO(k)FLUORANTHENE	NV	S	252	5.50E+05			8.00E-04	3.87E-05	1.59E-03	0.13	1.20E+00	3.90E-01		
BENZO(g,h,i)PERYLENE	NV	S	276	1.60E+06			2.60E-04	1.44E-07	5.90E-06	0.13			4.00E-02	4.00E-02
*BENZO(a)PYRENE	NV	S	252	5.50E+06			3.80E-03	4.90E-07	2.01E-05	0.13	1.20E+01	3.90E+00		
BERYLLIUM	NV	S	9							0.01		8.40E+00	2.00E-03	2.00E-06
*BIPHENYL, 1,1-	V	L	150	7.76E+03	4.04E-02	8.20E-06	7.50E+00	3.00E-04	1.23E-02	0.10			5.00E-02	5.00E-02
*BIS(2-CHLOROETHYL)ETHER	NV	L	142	7.60E+01	6.92E-02	7.53E-06	1.72E+04	1.80E-05	7.38E-04	0.10	2.50E+00	2.50E+00		
BIS(2-CHLOROISOPROPYL)ETHER	V	L	171	6.10E+01	6.31E-02	6.40E-06	1.70E+03	1.13E-04	4.63E-03	0.10	7.00E+00	3.50E+00	4.00E-02	4.00E-02
*BIS(2-ETHYLHEXYL)PHTHALATE	NV	L	391	1.00E+05			1.30E+00	3.00E-07	1.23E-05	0.10	3.00E-03	8.40E-03	2.00E-02	2.20E-02
BORON	NV	S	11							0.10			2.00E-01	5.70E-03
*BROMODICHLOROMETHANE	V	L	164	5.50E+01	2.98E-02	1.06E-05	6.74E+03	1.60E-03	6.56E-02	0.10	1.30E-01	1.30E-01	2.00E-02	2.00E-02
BROMOFORM	NV	S	253	1.10E+02			3.20E+03	5.32E-04	2.18E-02	0.10	7.90E-03	3.90E-03	2.00E-02	2.00E-02
*BROMOMETHANE	V	G	95	9.00E+00	7.28E-02	1.21E-05	1.52E+04	6.24E-03	2.56E-01	0.10			1.40E-03	1.40E-03
*CADMIUM	NV	S	112							0.001		1.50E+01	5.00E-04	5.71E-06
*CARBON TETRACHLORIDE	V	L	154	1.74E+02	7.80E-02	8.80E-06	7.93E+02	3.04E-02	1.25E+00	0.10	1.50E-01	1.50E-01	7.00E-04	1.14E-02
CHLORDANE	NV	S	410	4.40E+04			5.60E-02	4.79E-05	1.96E-03	0.04	1.30E+00	1.20E+00	5.00E-04	2.00E-04
CHLOROANILINE, p-	NV	S	128	6.40E+01	7.30E-02	8.70E-06	2.60E+03	3.31E-07	1.36E-05	0.10			4.00E-03	4.00E-03
CHLOROBENZENE	V	L	113	2.19E+02	1.04E-01	1.15E-05	4.72E+02	3.70E-03	1.52E-01	0.10			2.00E-02	1.70E-02
CHLOROETHANE	V	G	65	1.47E+01	1.04E-01	1.00E-05	5.70E+03	1.10E-02	4.51E-01	0.10	2.90E-03	2.90E-03	4.00E-01	2.90E+00
*CHLOROFORM	V	L	119	3.98E+01	1.10E-01	6.50E-06	7.92E+03	3.67E-03	1.50E-01	0.10	3.10E-02	1.90E-02	1.00E-02	1.40E-02
CHLOROMETHANE	V	G	51	3.50E+01	5.01E-01	9.46E-06	8.20E+03	2.40E-02	9.84E-01	0.10	2.60E-02	2.60E-02		8.60E-02
CHLOROPHENOL, 2-	V	L	132	3.98E+02			2.20E+04	3.91E-04	1.60E-02	0.10			5.00E-03	5.00E-03
*CHROMIUM (Total)	NV	S	52											
CHROMIUM III	NV	S	52							0.01			1.50E+00	
*CHROMIUM VI	NV	S	52							0.01		5.10E+02	3.00E-03	2.20E-06
*CHRYSENE	NV	S	228	4.00E+05	2.48E-02	6.21E-06	1.60E-03	9.46E-05	3.88E-03	0.13	1.20E-01	3.90E-02		5.70E-07
COBALT	NV	S	59							0.01			2.00E-02	
COPPER	NV	S	64							0.01			4.00E-02	
CYANIDE (Free)	V	S	26	1.70E+01	1.80E-01	1.80E-05	1.00E+06	1.30E-04	5.33E-03	0.10			2.00E-02	
*DIBENZO(a,h)ANTHTRACENE	NV	S	278	3.30E+06			5.00E-04	7.30E-08	2.99E-06	0.13	4.10E+00	4.10E+00		
*DIBROMOCHLOROMETHANE	V	S	208	4.68E+02	9.60E-02	1.00E-05	4.40E+03	8.50E-04	3.49E-02	0.10	9.40E-02	9.40E-02	2.00E-02	2.00E-02
*DIBROMO-3-CHLOROPROPANE, 1,2-	V	L	236	1.30E+02	2.12E-02	7.00E-06	1.20E+03	1.47E-04	6.03E-03	0.10	7.00E+00	7.00E+00	5.70E-05	5.70E-05
*DIBROMOETHANE, 1,2-	V	S	188	2.81E+01	7.33E-02	8.06E-06	3.40E+03	3.20E-04	1.31E-02	0.10	3.60E+00	2.50E-01	9.00E-03	2.60E-03

TABLE J. PHYSIO-CHEMICAL AND TOXICITY CONSTANTS USED IN MODELS.

CHEMICAL PARAMETER	Physical State		Molecular Weight	Organic carbon partition coefficient, K_{oc} (cm³/g)	Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Pure component water solubility, S (mg/L)	Henry's Law constant H (atm-m³/mol)	Henry's Law constant H' (unitless)	Skin Absorption Factor ABS (unitless)	Cancer Slope Factor Oral CSF_o $(mg/kg\text{-}d)^{-1}$	Cancer Slope Factor Inhaled CSF_i $(mg/kg\text{-}d)^{-1}$	Reference Dose Oral RfD_o (mg/kg-d)	Reference Dose Inhaled RfD_i (mg/kg-d)
DICHLOROBENZENE, 1,2-	V	L	147	6.17E+02	6.90E-02	7.90E-06	1.56E+02	1.90E-03	7.79E-02	0.10			9.00E-02	5.70E-02
DICHLOROBENZENE, 1,3-	V	L	147	6.17E+02	6.90E-02	7.90E-06	1.56E+02	1.90E-03	7.79E-02	0.10			3.00E-02	3.00E-02
*DICHLOROBENZENE, 1,4-	V	S	147	6.17E+02	6.90E-02	7.90E-06	7.38E+01	2.43E-03	9.96E-02	0.10	5.40E-03	4.00E-02	3.00E-02	2.30E-01
*DICHLOROBENZIDINE, 3,3-	NV	S	253	1.60E+03			3.11E+00	8.33E-07	3.42E-05	0.10	1.20E+00	1.20E+00		
*DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV	S	331	7.80E+05			1.60E-01	7.96E-06	3.26E-04	0.05	2.40E-01	2.40E-01		
*DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	NV	S	329	4.40E+06			4.00E-02	6.80E-05	2.79E-03	0.05	3.40E-01	3.40E-01		
*DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV	S	355	2.40E+05			3.00E-03	3.89E-05	1.59E-03	0.05	3.40E-01	3.40E-01	5.00E-04	5.00E-04
*DICHLOROETHANE, 1,1-	V	L	99	3.16E+01	7.42E-02	1.05E-05	5.06E+03	5.62E-03	2.30E-01	0.10	5.70E-03	5.70E-03	1.00E-01	1.40E-01
*DICHLOROETHANE, 1,2-	V	L	99	1.74E+01	1.04E-01	9.90E-06	8.52E+03	9.79E-04	4.01E-02	0.10	4.70E-02	7.30E-02		1.40E-03
*DICHLOROETHYLENE, 1,1-	V	L	97	5.89E+01	9.00E-02	1.04E-05	2.25E+03	2.61E-02	1.07E+00	0.10			5.00E-02	5.70E-02
DICHLOROETHYLENE, Cis 1,2-	V	L	97	3.55E+01	7.36E-02	1.13E-05	3.50E+03	4.08E-03	1.67E-01	0.10			1.00E-02	1.00E-02
DICHLOROETHYLENE, Trans 1,2-	V	L	97	5.25E+01	7.07E-02	1.19E-05	6.30E+03	9.38E-03	3.85E-01	0.10			2.00E-02	2.00E-02
DICHLOROPHENOL, 2,4-	NV	S	163	6.00E+03			4.50E+03	2.80E-06	1.15E-04	0.10			3.00E-03	3.00E-03
*DICHLOROPROPANE, 1,2-	V	L	113	4.37E+01	7.82E-02	8.73E-06	2.80E+03	2.80E-03	1.15E-01	0.10	3.60E-02	3.60E-02	1.10E-03	1.10E-03
*DICHLOROPROPENE, 1,3-	V	L	111	4.57E+01	6.26E-02	1.00E-05	2.80E+03	1.77E-02	7.26E-01	0.10	9.10E-02	5.50E-02	2.00E-02	2.00E-02
*DIELDRIN	NV	S	381	7.40E+03			1.86E-01	5.84E-05	2.39E-03	0.05	1.60E+01	1.60E+01	5.00E-05	5.00E-05
DIETHYLPHTHALATE	NV	S	222	1.40E+02			8.96E+02	1.14E-06	4.67E-05	0.10			8.00E-01	8.00E-01
DIMETHYLPHTHALATE	NV	S	194	1.40E+02			5.00E+03	1.05E-07	4.31E-06	0.10			1.00E+01	1.00E+01
DIMETHYLPHENOL, 2,4-	NV	S	122	4.00E+01	5.84E-02	8.69E-06	7.87E+03	1.70E-05	6.97E-04	0.10			2.00E-02	2.00E-02
DINITROPHENOL, 2,4-	NV	S	184	1.70E+01			5.60E+03	6.45E-10	2.64E-08	0.10			2.00E-03	2.00E-03
*DINITROTOLUENE, 2,4-	NV	S	182	4.50E+01			2.70E+02	4.50E-06	1.85E-04	0.10	3.10E-01	3.10E-01	2.00E-03	2.00E-03
*DIOXANE, 1,4-	NV	L	88	3.50E+00			1.00E+06	3.00E-06	1.23E-04	0.10	2.70E-02	2.70E-02		8.57E-01
*DIOXIN (2,3,7,8-TCDD)	NV	S	322	1.30E+07			1.40E+01	8.10E-05	3.32E-03	0.02	1.30E+05	1.30E+05		1.14E-08
ENDOSULFAN	NV	S	407	3.20E+03			1.50E-01	1.00E-05	4.10E-04	0.10			6.00E-03	6.00E-03
ENDRIN	NV	S	381	1.70E+03			2.60E-01	7.51E-06	3.08E-04	0.05			3.00E-04	3.00E-04
ETHANOL	NV	L	46	3.09E-01			1.00E+06	6.29E-06	2.58E-04	0.10			not available	not available
ETHYLBENZENE	V	L	106	3.63E+02	7.50E-02	7.80E-06	1.69E+02	7.88E-03	3.23E-01	0.10			1.00E-01	5.70E-01
FLUORANTHENE	NV	S	202	3.80E+04			2.65E-01	6.50E-06	2.67E-04	0.13			4.00E-02	4.00E-02
FLUORENE	V	S	166	1.38E+04	6.08E-02	7.88E-06	1.90E+00	7.70E-05	3.16E-03	0.10			4.00E-02	4.00E-02
*HEPTACHLOR	NV	S	373	2.20E+04			5.60E-02	1.48E-03	6.07E-02	0.05	4.10E+00	4.10E+00	5.00E-04	5.00E-04
*HEPTACHLOR EPOXIDE	NV	S	389	2.30E+04			3.50E-01	3.16E-05	1.30E-03	0.10	5.50E+00	5.50E+00	1.30E-05	1.30E-05
*HEXACHLOROBENZENE	NV	S	285	1.20E+06			1.10E-01	1.70E-03	6.97E-02	0.10	1.80E+00	1.80E+00	8.00E-04	8.00E-04
HEXACHLOROBUTADIENE	NV	S	261	2.90E+04			2.00E+00	2.56E-02	1.05E+00	0.10	7.80E-02	7.80E-02	3.00E-04	3.00E-04
*HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV	S	291	3.70E+03			7.00E+00	4.93E-07	2.02E-05	0.05	1.10E+00	1.10E+00	3.00E-04	3.00E-04
*HEXACHLOROETHANE	NV	S	237	2.00E+04			5.00E+01	9.85E-03	4.04E-01	0.10	3.90E-02	3.90E-02	1.00E-03	1.00E-03
*INDENO(1,2,3-cd)PYRENE	NV	S	276	1.60E+06			5.30E-04	6.95E-08	2.85E-06	0.13	1.20E+00	3.90E-01		
LEAD	NV	S	207							0.01				
MERCURY	V	S	201							0.10			3.00E-04	2.60E-05
METHOXYCHLOR	NV	S	347	7.90E+04			4.00E-02	1.58E-05	6.48E-04	0.05			5.00E-03	5.00E-03
*METHYLENE CHLORIDE	V	L	85	1.11E+01	1.01E-01	1.17E-05	1.32E+04	2.19E-03	8.98E-02	0.10	1.40E-02	3.50E-03	6.00E-02	8.60E-01
METHYL ETHYL KETONE	V	L	72	4.50E+00	8.95E-02	9.80E-06	2.68E+05	2.74E-05	1.12E-03	0.10			6.00E-01	2.90E-01
METHYL ISOBUTYL KETONE	V	L	100	1.34E+02	7.50E-02	7.80E-06	1.90E+04	1.40E-04	5.74E-03	0.10			8.00E-02	2.30E-02
METHYL MERCURY	NV	S	216							0.10			1.00E-04	1.00E-04

TABLE J. PHYSIO-CHEMICAL AND TOXICITY CONSTANTS USED IN MODELS.

CHEMICAL PARAMETER	Physical State	Molecular Weight	Organic carbon partition coefficient, Koc (cm³/g)	Diffusivity in air, Da (cm²/s)	Diffusivity in water, Dw (cm²/s)	Pure component water solubility, S (mg/L)	Henry's Law constant H (atm-m³/mol)	Henry's Law constant H' (unitless)	Skin Absorption Factor ABS (unitless)	Cancer Slope Factor Oral CSFo (mg/kg-d)⁻¹	Cancer Slope Factor Inhaled CSFI (mg/kg-d)⁻¹	Reference Dose Oral RfDo (mg/kg-d)	Reference Dose Inhaled RfDi (mg/kg-d)
METHYLNAPHTHALENE (total 1- & 2-)	V	S	142	7.20E+02	5.90E-02	7.50E-06	2.60E+01	2.90E-04	1.19E-02	0.10			4.00E-02	4.00E-02
*METHYL TERT BUTYL ETHER	V	L	88	6.00E+00	8.00E-02	1.00E-05	1.50E+05	5.87E-04	2.41E-02	0.10	1.80E-03	9.10E-04	8.60E-01	2.28E+00
MOLYBDENUM	NV	S	96							0.01			5.00E-03	
NAPHTHALENE	V	S	128	1.19E+03	5.90E-02	7.50E-06	3.10E+01	4.83E-04	1.98E-02	0.10	1.20E-01	1.20E-01	2.00E-02	2.57E-03
*NICKEL	NV	S	59							0.0002		9.10E-01	2.00E-02	
*PENTACHLOROPHENOL	NV	S	266	3.20E+04			1.40E+04	2.80E-06	1.15E-04	0.25	8.10E-02	1.80E-02	3.00E-02	3.00E-02
PERCHLORATE	NV	S	100				2.00E+05			0.01			1.00E-04	
PHENANTHRENE	V	S	178	1.40E+04			8.16E-01	3.93E-05		0.10			4.00E-02	4.00E-02
PHENOL	NV	S	94	9.10E+01			8.00E+04	1.30E-06	5.33E-05	0.10			3.00E-01	3.00E-01
POLYCHLORINATED BIPHENYLS (PCBs)	NV	S	327 (ave)	3.30E+04			3.20E-02	5.20E-04	2.13E-02	0.14	2.00E+00	2.00E+00	2.00E-05	2.00E-05
PYRENE	V	S	202	1.05E+05	2.72E-02	7.24E-06	1.35E-01	1.10E-05	4.51E-04	0.10			3.00E-02	3.00E-02
SELENIUM	NV	S	79							0.01			5.00E-03	5.71E-03
SILVER	NV	S	47							0.01			5.00E-03	
STYRENE	V	L	104	7.76E+02	7.10E-02	8.00E-06	3.10E+02	2.75E-03	1.13E-01	0.10			2.00E-01	2.90E-01
tert-BUTYL ALCOHOL	V	L	74	3.70E+01	9.00E-02	9.10E-06	1.00E+06	1.17E-05	4.80E-04	0.10	3.30E-03	3.30E-03		
TETRACHLOROETHANE, 1,1,1,2-	V	L	168	9.37E+01	7.10E-02	7.90E-06	2.97E+03	3.45E-04	1.41E-02	0.10	2.60E-02	2.60E-02	3.00E-02	3.00E-02
*TETRACHLOROETHANE, 1,1,2,2-	V	L	168	9.37E+01	7.10E-02	7.90E-06	2.97E+03	3.45E-04	1.41E-02	0.10	2.70E-01	2.00E-01	6.00E-02	6.00E-02
*TETRACHLOROETHYLENE	V	L	166	1.55E+02	7.20E-02	8.20E-06	2.00E+02	1.84E-02	7.54E-01	0.10	5.40E-01	2.10E-02	1.00E-02	1.00E-02
THALLIUM	NV	S	204							0.01			6.60E-05	
TOLUENE	V	L	92	1.82E+02	8.70E-02	8.60E-06	5.26E+02	6.64E-03	2.72E-01	0.10			2.00E-01	8.57E-02
TOXAPHENE	NV	S	414	4.90E+03			3.00E+00	2.10E-01	8.61E+00	0.05	1.20E+00	1.20E+00		
TPH (gasolines)	V	L	108	5.00E+03	7.00E-02	7.80E-06	1.50E+02	7.20E-04	2.95E-02	0.10			3.00E-02	1.40E-02
TPH (middle distillates)	V	L	170	5.00E+03	7.00E-02	7.80E-06	5.00E+00	7.20E-04	2.95E-02	0.10			3.00E-02	1.40E-02
TPH (residual fuels)	NV	L/S		5.00E+03			5.00E+00			0.05			3.00E-02	1.40E-02
*TRICHLOROBENZENE, 1,2,4-	V	S	180	1.78E+03	3.00E-02	8.23E-06	3.00E+02	1.42E-03	5.82E-02	0.10	3.60E-03		1.00E-02	1.00E-03
TRICHLOROETHANE, 1,1,1-	V	L	133	1.10E+02	7.80E-02	8.80E-06	1.33E+03	1.72E-02	7.05E-01	0.10			2.80E-01	6.30E-01
*TRICHLOROETHANE, 1,1,2-	V	L	133	5.01E+01	7.80E-02	8.80E-06	4.42E+03	9.13E-04	3.74E-02	0.10	7.20E-02	5.70E-02	4.00E-03	4.00E-03
*TRICHLOROETHYLENE	V	L	131	1.66E+02	7.90E-02	9.10E-06	1.10E+03	1.03E-02	4.22E-01	0.10	1.30E-02	7.00E-03	3.00E-04	1.70E-01
*TRICHLOROPHENOL, 2,4,5-	V	S	198	8.90E+01	2.9E-02	7.0E-06	1.19E+03	2.18E-04	8.94E-03	0.10			1.00E-01	1.00E-01
*TRICHLOROPHENOL, 2,4,6-	NV	S	198	2.00E+03			8.00E+02	4.00E-06	1.64E-04	0.10	7.00E-02	7.00E-02	7.00E-03	
VANADIUM	NV	S	51							0.01				

TABLE J. PHYSIO-CHEMICAL AND TOXICITY CONSTANTS USED IN MODELS.

CHEMICAL PARAMETER	Physical State		Molecular Weight	Organic carbon partition coefficient, Koc (cm³/g)	Diffusivity in air, Da (cm²/s)	Diffusivity in water, Dw (cm²/s)	Pure component water solubility, S (mg/L)	Henry's Law constant H (atm-m³/mol)	Henry's Law constant H' (unitless)	Skin Absorption Factor ABS (unitless)	Cancer Slope Factor Oral CSFo (mg/kg-d)⁻¹	Cancer Slope Factor Inhaled CSFi (mg/kg-d)⁻¹	Reference Dose Oral RfDo (mg/kg-d)	Reference Dose Inhaled RfDi (mg/kg-d)
*VINYL CHLORIDE	V	G	63	1.86E+01	1.06E-01	1.23E-06	2.76E+03	2.70E-02	1.11E+00	0.10	2.70E-01	2.70E-01	3.00E-03	2.86E-02
XYLENES	V	L	106	4.07E+02	7.00E-02	7.80E-06	1.61E+02	7.34E-03	3.01E-01	0.10			2.00E-01	2.00E-01
ZINC	NV	S	65							0.01			3.00E-01	

Red: Constant or toxicity factor updated with respect to value presented in July 2003 ESL document. Majority of changes reflect standardization with values used in December 2004 CHHSLs document (CalEPA 2004b). Ethanol added to February 2005 ESLs.

Notes:

Physical state of chemical at ambient conditions (V - volatile, NV - nonvolatile, S - solid, L - liquid, G - gas).

Chemical considered to be "volatile" if Henry's number (atm m3/mole) >0.00001 and molecular weight <200.

Dibromochloromethane, dibromochloropropane and pyrene considered volatile for purposes of modeling (USEPA 2004). (Molecular weight adjusted to 199 in column E (hidden) to permit generation of volatilization factor in soil direct-exposure models.)

TPH -Total Petroleum Hydrocarbons. RfD values from MADEP 2002. See text for discussion of different TPH categories.

TPH as gasolines and middle distillates diffusivity constants based on xylenes. (Required for direct exposure models. Does not significantly affect action levels. See Chapter 4)

Physio-chemical constants and ABS values from (in order of preference): OEHHA CHHSLs (CalEPA 2004a), USEPA Region IX PRGs (USEPA 2004) or Ontario MOEE (MOEE 1996), except as noted. OEHHA screening numbers for arsenic and dioxin equate to ABS values of 0.01 and 0.02 (used above), versus 0.04 and 0.002 as noted in OEHHA CHHSLs document.

Physio-chemical constants for dioxin, polychlorinated biphenyls and toxaphene from ATSDR 2001a. PCB solubility from MOEE (1996).

Physio-chemical constants for 1,4 Dioxane from "Solvent Stabilizers - White Paper" (Mohr 2001).

Physio-chemical constants for TBA from Assessment and Management of MtBE Impacted Sites (RWQCB 2001). Oral cancer slope factor from OEHHA (CalEPA 1999b). Inhalation CSF inferred from oral CSF.

Physio-chemical constants for TBA for ethanol from Fate and Transport of Ethanol-Blended Gasoline in the Environment (Ulrich 1999). Koc estimated from log Kow of -0.31 presented in Toxnet (NLM 2005) using

Molecular weight, solubility, Henry's Law Constant for ethanol from USEPA as presented in USEPA Region IX PRGs.

Koc = kow x 0.63 (in Fetter 1993, conversion for miscellaneous organics). Toxicity factors for ethanol not available.

Koc = kow x 0.63 for xylenes based on m-xylene.

Physio-chemicals and toxicity constants for xylenes based on m-xylene.

Cancer Slope Factors from OEHHA CHHLs document (CalEPA 2004b) and DTSC database (CalEPA 2004a) where available (marked by "***"); otherwise from USEPA as presented in Region IX PRGs (USEPA 2004). Reference dose factors from OEHHA CHHLs document (red in electronic versions of this table) as available; otherwise as presented in USEPA Region IX PRGs.

Diffusivity constants for methylnaphthalene not available. Constants presented based on naphthalene.

PCBs based on updated USEPA slope factors as presented in USEPA Region IX Preliminary Remediation Goals document (USEPA 2004).

RfDs for acenaphthylene, methylnaphthylene, and phenanthrene based on fluorene; RfDs for benzo(g,h,i)perylene based on fluoranthene (after MADEP 1994).

TABLE K-1. DIRECT-EXPOSURE SCREENING LEVELS
[1]RESIDENTIAL EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10^{-6}) (mg/kg)	Noncarcinogens [2](HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
ACENAPHTHENE	6.0E+02	noncarcinogenic effects	-	6.0E+02	3.0E+03	NA
ACENAPHTHYLENE	4.4E+02	=fluorene	-	4.4E+02	2.2E+03	NA
ACETONE	2.7E+03	noncarcinogenic effects	-	2.7E+03	1.3E+04	1.0E+05
*ALDRIN	3.2E-02	carcinogenic effects	3.2E-02	4.1E-01	2.1E+00	NA
ANTHRACENE	3.5E+03	noncarcinogenic effects	-	3.5E+03	1.7E+04	NA
ANTIMONY	6.1E+00	noncarcinogenic effects	-	6.1E+00	3.0E+01	NA
*ARSENIC	6.0E-02	carcinogenic effects	6.0E-02	4.2E+00	2.1E+01	NA
BARIUM	1.0E+03	noncarcinogenic effects	-	1.0E+03	5.2E+03	NA
*BENZENE	1.8E-01	carcinogenic effects	1.8E-01	1.0E+01	5.2E+01	8.7E+02
*BENZO(a)ANTHRACENE	3.8E-01	carcinogenic effects	3.8E-01	-	-	NA
*BENZO(b)FLUORANTHENE	3.8E-01	carcinogenic effects	3.8E-01	-	-	NA
*BENZO(k)FLUORANTHENE	3.8E-01	carcinogenic effects	3.8E-01	-	-	NA
BENZO(g,h,i)PERYLENE	4.6E+02	noncarcinogenic effects	-	4.6E+02	2.3E+03	NA
*BENZO(a)PYRENE	3.8E-02	carcinogenic effects	3.8E-02	-	-	NA
*BERYLLIUM	2.9E+01	noncarcinogenic effects	1.1E+03	2.9E+01	1.5E+02	NA
BIPHENYL, 1,1-	4.9E+02	noncarcinogenic effects	-	4.9E+02	2.5E+03	NA
*BIS(2-CHLOROETHYL)ETHER	8.5E-02	carcinogenic effects	8.5E-02	-	-	9.6E+03
BIS(2-CHLOROISOPROPYL)ETHER	2.6E+00	carcinogenic effects	2.6E+00	1.7E+02	8.7E+02	7.9E+02
*BIS(2-ETHYLHEXYL)PHTHALATE	1.6E+02	carcinogenic effects	1.6E+02	2.4E+02	1.2E+03	NA
BORON	2.4E+03	noncarcinogenic effects	-	2.4E+03	1.2E+04	NA
*BROMODICHLOROMETHANE	3.8E-01	carcinogenic effects	3.8E-01	4.2E+01	2.1E+02	3.0E+03
BROMOFORM	6.1E+01	carcinogenic effects	6.1E+01	2.4E+02	1.2E+03	NA
BROMOMETHANE	7.5E-01	noncarcinogenic effects	-	7.5E-01	3.7E+00	3.1E+03
*CADMIUM	1.7E+00	noncarcinogenic effects	1.7E+00	7.8E+00	3.9E+01	NA
*CARBON TETRACHLORIDE	8.9E-02	carcinogenic effects	8.9E-02	3.9E+00	2.0E+01	1.1E+03
*CHLORDANE	4.4E-01	carcinogenic effects	4.4E-01	7.0E+00	3.5E+01	NA
CHLOROANILINE, p-	4.9E+01	noncarcinogenic effects	-	4.9E+01	2.4E+02	NA
CHLOROBENZENE	2.9E+01	noncarcinogenic effects	-	2.9E+01	1.5E+02	6.8E+02
CHLOROETHANE	3.0E+00	carcinogenic effects	3.0E+00	9.6E+02	4.8E+03	1.6E+03
*CHLOROFORM	8.8E-01	carcinogenic effects	8.8E-01	1.1E+01	5.3E+01	2.9E+03
CHLOROMETHANE	3.0E-01	carcinogenic effects	3.0E-01	3.1E+01	1.6E+02	4.1E+03
CHLOROPHENOL, 2-	1.2E+01	noncarcinogenic effects	-	1.2E+01	6.0E+01	5.5E+04
CHROMIUM (Total)	-	-	-	-	-	NA
CHROMIUM III	2.3E+04	noncarcinogenic effects	-	2.3E+04	1.1E+05	NA
*CHROMIUM VI	1.8E+00	trench/construction worker	1.7E+01	4.3E+01	2.2E+02	NA
*CHRYSENE	3.8E+00	carcinogenic effects	3.8E+00	-	-	NA
COBALT	1.0E+01	trench/construction worker	9.1E+02	1.3E+02	6.6E+02	NA

TABLE K-1. DIRECT-EXPOSURE SCREENING LEVELS
[1]RESIDENTIAL EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10^{-6}) (mg/kg)	Noncarcinogens [2](HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
COPPER	6.1E+02	noncarcinogenic effects	-	6.1E+02	3.0E+03	NA
CYANIDE (Free)	2.4E+02	noncarcinogenic effects	-	2.4E+02	1.2E+03	NA
*DIBENZO(a,h)ANTHTRACENE	1.1E-01	carcinogenic effects	1.1E-01			NA
*DIBROMOCHLOROMETHANE	9.4E-01	carcinogenic effects	9.4E-01	7.1E+01	3.6E+02	NA
*1,2-DIBROMO-3-CHLOROPROPANE	2.7E-02	carcinogenic effects	2.7E-02	3.7E-01	1.9E+00	1.1E+03
*DIBROMOETHANE, 1,2-	8.7E-02	carcinogenic effects	8.7E-02	6.9E+00	3.5E+01	NA
DICHLOROBENZENE, 1,2-	2.1E+02	noncarcinogenic effects	-	2.1E+02	1.0E+03	6.0E+02
DICHLOROBENZENE, 1,3-	9.9E+01	noncarcinogenic effects	-	9.9E+01	5.0E+02	6.0E+02
*DICHLOROBENZENE, 1,4-	2.1E+00	carcinogenic effects	2.1E+00	2.6E+02	1.3E+03	NA
*DICHLOROBENZIDINE, 3,3-	4.0E-01	carcinogenic effects	4.0E-01	-	-	NA
*DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.3E+00	carcinogenic effects	2.3E+00	-	-	NA
*DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.6E+00	carcinogenic effects	1.6E+00	-	-	NA
*DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.6E+00	carcinogenic effects	1.6E+00	6.9E+00	3.4E+01	NA
*DICHLOROETHANE, 1,1-	2.7E+00	carcinogenic effects	2.7E+00	9.7E+01	4.8E+02	1.7E+03
*DICHLOROETHANE, 1,2-	3.4E-01	carcinogenic effects	3.4E-01	1.7E+00	8.4E+00	1.8E+03
DICHLOROETHYLENE, 1,1-	2.4E+01	noncarcinogenic effects	-	2.4E+01	1.2E+02	1.5E+03
DICHLOROETHYLENE, Cis 1,2-	8.4E+00	noncarcinogenic effects	-	8.4E+00	4.2E+01	1.2E+03
DICHLOROETHYLENE, Trans 1,2-	1.4E+01	noncarcinogenic effects	-	1.4E+01	6.8E+01	3.1E+03
DICHLOROPHENOL, 2,4-	3.7E+01	noncarcinogenic effects	-	3.7E+01	1.8E+02	NA
*DICHLOROPROPANE, 1,2-	6.3E-01	carcinogenic effects	6.3E-01	1.1E+00	5.6E+00	1.1E+03
*DICHLOROPROPENE, 1,3-	2.1E-01	carcinogenic effects	2.1E-01	1.1E+01	5.4E+01	1.4E+03
*DIELDRIN	3.4E-02	carcinogenic effects	3.4E-02	6.9E-01	3.4E+00	NA
DIETHYLPHTHALATE	9.8E+03	noncarcinogenic effects	-	9.8E+03	4.9E+04	NA
DIMETHYLPHTHALATE	1.2E+05	noncarcinogenic effects	-	1.2E+05	6.1E+05	NA
DIMETHYLPHENOL, 2,4-	1.4E+02	noncarcinogenic effects	-	1.4E+02	6.8E+02	NA
DINITROPHENOL, 2,4-	2.4E+01	noncarcinogenic effects	-	2.4E+01	1.2E+02	NA
*DINITROTOLUENE, 2,4-	1.6E+00	carcinogenic effects	1.6E+00	2.4E+01	1.2E+02	NA
*1,4 DIOXANE	1.8E+01	carcinogenic effects	1.8E+01	3.5E+08	1.8E+09	NA
*DIOXIN (2,3,7,8-TCDD)	4.6E-06	carcinogenic effects	4.6E-06	4.7E+00	2.4E+01	NA
ENDOSULFAN	7.3E+01	noncarcinogenic effects	-	7.3E+01	3.7E+02	NA
ENDRIN	4.1E+00	noncarcinogenic effects	-	4.1E+00	2.1E+01	NA
ETHANOL	4.0E+02	saturation limit	-	5.3E+02	2.7E+03	4.0E+02
ETHYLBENZENE	4.6E+02	noncarcinogenic effects	-	4.6E+02	2.3E+03	NA
FLUORANTHENE	4.4E+02	noncarcinogenic effects	-	4.4E+02	2.2E+03	NA
FLUORENE		not available				
*HEPTACHLOR	1.3E-01	carcinogenic effects	1.3E-01	6.9E+00	3.4E+01	NA
*HEPTACHLOR EPOXIDE	8.8E-02	carcinogenic effects	8.8E-02	1.6E-01	7.9E-01	NA

TABLE K-1. DIRECT-EXPOSURE SCREENING LEVELS
[1]RESIDENTIAL EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10^{-6}) (mg/kg)	Noncarcinogens [2](HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
*HEXACHLOROBENZENE	2.7E-01	carcinogenic effects	2.7E-01	9.8E+00	4.9E+01	NA
HEXACHLOROBUTADIENE	3.7E+00	noncarcinogenic effects	6.2E+00	3.7E+00	1.8E+01	NA
*HEXACHLOROCYCLOHEXANE (gamma) LINDANE	5.0E-01	carcinogenic effects	5.0E-01	4.1E+00	2.1E+01	NA
*HEXACHLOROETHANE	1.2E+01	noncarcinogenic effects	1.2E+01	1.2E+01	6.1E+01	NA
*INDENO(1,2,3-cd)PYRENE	3.8E-01	carcinogenic effects	3.8E-01	-	-	NA
LEAD	1.50E+02	OEHHA (CalEPA 2004b)	-	-	-	NA
MERCURY	3.7E+00	noncarcinogenic effects	-	3.7E+00	1.8E+01	NA
METHOXYCHLOR	6.9E+01	noncarcinogenic effects	-	6.9E+01	3.4E+02	NA
*METHYLENE CHLORIDE	4.1E+00	carcinogenic effects	4.1E+00	3.5E+02	1.7E+03	2.4E+03
METHYL ETHYL KETONE	1.4E+03	noncarcinogenic effects	-	1.4E+03	7.0E+03	3.4E+04
METHYL ISOBUTYL KETONE	1.5E+02	noncarcinogenic effects	-	1.5E+02	7.6E+02	1.7E+04
METHYL MERCURY	1.2E+00	noncarcinogenic effects	-	1.2E+00	6.1E+00	NA
METHYLNAPHTHALENE (total 1- & 2-)	2.6E+02	noncarcinogenic effects	-	2.6E+02	1.3E+03	NA
*METHYL TERT BUTYL ETHER	3.0E+01	carcinogenic effects	3.0E+01	2.5E+03	1.3E+04	2.1E+04
MOLYBDENUM	7.6E+01	noncarcinogenic effects	-	7.6E+01	3.8E+02	NA
NAPHTHALENE	1.5E+00	carcinogenic effects	1.5E+00	3.0E+01	1.5E+02	NA
*NICKEL	3.1E+02	noncarcinogenic effects	9.8E+03	3.1E+02	1.6E+03	NA
*PENTACHLOROPHENOL	4.4E+00	carcinogenic effects	4.4E+00	2.8E+02	1.4E+03	NA
PERCHLORATE	1.5E+00	noncarcinogenic effects	-	1.5E+00	7.6E+00	NA
PHENANTHRENE	4.4E+02	=fluorene	-	4.4E+02	2.2E+03	NA
PHENOL	3.7E+03	noncarcinogenic effects	-	3.7E+03	1.8E+04	NA
*POLYCHLORINATED BIPHENYLS (PCBs)	2.2E-01	carcinogenic effects	2.2E-01	2.2E-01	1.1E+00	NA
PYRENE	3.6E+02	noncarcinogenic effects	-	3.6E+02	1.8E+03	NA
SELENIUM	7.6E+01	noncarcinogenic effects	-	7.6E+01	3.8E+02	NA
SILVER	7.6E+01	noncarcinogenic effects	-	7.6E+01	3.8E+02	NA
STYRENE	8.1E+02	noncarcinogenic effects	-	8.1E+02	4.0E+03	1.5E+03
tert-BUTYL ALCOHOL	5.7E+01	carcinogenic effects	5.7E+01	-	-	3.2E+05
TETRACHLOROETHANE, 1,1,1,2-	3.0E+00	carcinogenic effects	3.0E+00	9.7E+01	4.8E+02	2.0E+03
*TETRACHLOROETHANE, 1,1,2,2-	3.7E-01	carcinogenic effects	3.7E-01	1.9E+02	9.7E+02	2.0E+03
*TETRACHLOROETHYLENE	4.3E-01	carcinogenic effects	4.3E-01	7.4E+00	3.7E+01	2.3E+02
THALLIUM	1.0E+00	noncarcinogenic effects	-	1.0E+00	5.0E+00	NA
TOLUENE	1.0E+02	noncarcinogenic effects	-	1.0E+02	5.1E+02	6.5E+02
TOXAPHENE	4.6E-01	carcinogenic effects	4.6E-01	-	-	NA
TPH (gasolines)	4.0E+02	noncarcinogenic effects	-	4.0E+02	8.0E+02	NA
TPH (middle distillates)	4.0E+02	noncarcinogenic effects	-	4.0E+02	8.0E+02	NA
TPH (residual fuels)	1.0E+03	noncarcinogenic effects	-	1.0E+03	2.1E+03	NA
*TRICHLOROBENZENE, 1,2,4-	1.2E+01	noncarcinogenic effects	1.3E+02	1.2E+01	6.0E+01	NA

TABLE K-1. DIRECT-EXPOSURE SCREENING LEVELS
[1]RESIDENTIAL EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10^{-6}) (mg/kg)	Noncarcinogens [2](HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
TRICHLOROETHANE, 1,1,1-	3.8E+02	noncarcinogenic effects	-	3.8E+02	1.9E+03	1.2E+03
*TRICHLOROETHANE, 1,1,2-	6.8E-01	carcinogenic effects	6.8E-01	6.9E+00	3.4E+01	1.8E+03
*TRICHLOROETHYLENE	2.9E+00	carcinogenic effects	2.9E+00	3.6E+00	1.8E+01	1.3E+03
TRICHLOROPHENOL, 2,4,5-	5.0E+02	noncarcinogenic effects	-	5.0E+02	2.5E+03	NA
*TRICHLOROPHENOL, 2,4,6-	6.9E+00	carcinogenic effects	6.9E+00	-	-	NA
VANADIUM	1.1E+02	noncarcinogenic effects	-	1.1E+02	5.3E+02	NA
*VINYL CHLORIDE	2.5E-02	carcinogenic effects	2.5E-02	7.4E+00	3.7E+01	1.2E+03
XYLENES	3.3E+02	noncarcinogenic effects	-	3.3E+02	1.6E+03	4.2E+02
ZINC	4.6E+03	noncarcinogenic effects	-	4.6E+03	2.3E+04	NA

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Primary source: USEPA Region IX Preliminary Remediation Goals (PRGs, USEPA 2004), modified as noted below. See text for discussion.

Notes:

1. "Residential" screening levels generally considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.).

2. Alternative direct-exposure screening levels for TPH based on a Hazard Quotient of 0.5 (refer to text Section 3.2).

See text for equations and assumptions used in models.

Final screening level is lowest of individual screening levels for carcinogenic effects and noncarcinogenic effects (based on HQ=0.2) or screening level for construction/trench workers if lower (see Table K-3). Saturation limit used as upper limit for volatile organic compounds that are liquid at ambient conditions (see text).

Carcinogens: Based on target cancer risk of 10^{-6}, modified with respect to CalEPA/OEHHA slope factors when available (marked by "*"). Screening levels for PCBs based on updated USEPA slope factors as presented in USEPA Region IX Preliminary Remediation Goals document (USEPA 2004).

Noncarcinogens: Adjusted to target hazard quotient of 0.2 for use in tables for all chemicals except TPH (TPH adjusted to HQ of 0.5; see Sections 1.3 and 3.4 in text). Screening levels based on hazard quotient of 1.0 provided for reference.

Saturation: Theoretical soil saturation level in the absence of free product; calculated for volatile organic compounds that are liquids under ambient conditions (refer to Table J).

TPH:Total Petroleum Hydrocarbons. See text for discussion of different TPH categories. Direct exposure screening levels after Massachusetts Department of Environmental Protection (see text).

Direct-exposure screening level for lead from Office of Human Hazard Evaluation CHHSLs (CalEPA 2004b).

TABLE K-2. DIRECT-EXPOSURE SCREENING LEVELS
COMMERCIAL/INDUSTRIAL WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10⁻⁶) (mg/kg)	Noncarcinogens (HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
ACENAPHTHENE	4.4E+03	noncarcinogenic effects	-	4.4E+03	2.2E+04	NA
ACENAPHTHYLENE	3.7E+03	=fluorene	-	3.7E+03	1.8E+04	NA
ACETONE	1.0E+04	noncarcinogenic effects	-	1.0E+04	5.2E+04	1.0E+05
*ALDRIN	1.3E-01	carcinogenic effects	1.3E-01	4.6E+00	2.3E+01	NA
ANTHRACENE	3.1E+04	noncarcinogenic effects	-	3.1E+04	1.6E+05	NA
ANTIMONY	7.7E+01	noncarcinogenic effects	-	7.7E+01	3.8E+02	NA
*ARSENIC	2.4E-01	carcinogenic effects	2.4E-01	4.8E+01	2.4E+02	NA
BARIUM	2.5E+03	trench/construction worker	-	1.3E+04	6.3E+04	NA
*BENZENE	3.8E-01	carcinogenic effects	3.8E-01	4.2E-01	2.1E+02	8.7E+02
*BENZO(a)ANTHRACENE	1.3E+00	carcinogenic effects	1.3E+00	-	-	NA
*BENZO(b)FLUORANTHENE	1.3E+00	carcinogenic effects	1.3E+00	-	-	NA
*BENZO(k)FLUORANTHENE	1.3E+00	carcinogenic effects	1.3E+00	-	-	NA
BENZO(g,h,i)PERYLENE	4.4E+03	noncarcinogenic effects	-	4.4E+03	2.2E+04	NA
*BENZO(a)PYRENE	1.3E-01	carcinogenic effects	1.3E-01	-	-	NA
*BERYLLIUM	3.6E+01	trench/construction worker	2.2E+03	3.4E+02	1.7E+03	NA
BIPHENYL, 1,1-	3.6E+03	noncarcinogenic effects	-	3.6E+03	1.8E+04	NA
*BIS(2-CHLOROETHYL)ETHER	2.2E-01	carcinogenic effects	2.2E-01	-	-	9.6E+03
BIS(2-CHLOROISOPROPYL)ETHER	6.5E+00	carcinogenic effects	6.5E+00	7.5E+02	3.8E+03	7.9E+02
*BIS(2-ETHYLHEXYL)PHTHALATE	5.7E+02	carcinogenic effects	5.7E+02	2.5E+03	1.2E+04	NA
BORON	2.5E+04	noncarcinogenic effects	-	2.5E+04	1.2E+05	NA
*BROMODICHLOROMETHANE	8.4E-01	carcinogenic effects	8.4E-01	1.6E+02	7.8E+02	3.0E+03
BROMOFORM	2.2E+02	carcinogenic effects	2.2E+02	2.5E+03	1.2E+04	NA
BROMOMETHANE	2.5E+00	noncarcinogenic effects	-	2.5E+00	1.3E+01	3.1E+03
*CADMIUM	7.4E+00	carcinogenic effects	7.4E+00	1.0E+02	5.0E+02	NA
*CARBON TETRACHLORIDE	1.9E-01	carcinogenic effects	1.9E-01	1.9E+01	9.3E+01	1.1E+03
*CHLORDANE	1.7E+00	carcinogenic effects	1.7E+00	8.1E+01	4.0E+02	NA
CHLOROANILINE, p-	4.9E+02	noncarcinogenic effects	-	4.9E+02	2.5E+03	NA
CHLOROBENZENE	1.0E+02	noncarcinogenic effects	-	1.0E+02	5.2E+02	6.8E+02
CHLOROETHANE	6.4E+00	carcinogenic effects	6.4E+00	3.6E+03	1.8E+04	1.6E+03
*CHLOROFORM	1.9E+00	carcinogenic effects	1.9E+00	3.7E+01	1.8E+02	2.9E+03
CHLOROMETHANE	6.3E-01	carcinogenic effects	6.3E-01	1.0E+02	5.1E+02	4.1E+03
CHLOROPHENOL, 2-	4.5E+01	noncarcinogenic effects	-	4.5E+01	2.3E+02	5.5E+04
CHROMIUM (Total)	-		-	-	-	NA
CHROMIUM III	2.9E+05	noncarcinogenic effects	-	2.9E+05	1.4E+06	NA
*CHROMIUM VI	1.8E+00	trench/construction worker	3.7E+01	4.8E+02	2.4E+03	NA
*CHRYSENE	1.3E+01	carcinogenic effects	1.3E+01	-	-	NA
COBALT	1.0E+01	trench/construction worker	1.9E+03	6.4E+02	3.2E+03	NA

TABLE K-2. DIRECT-EXPOSURE SCREENING LEVELS
COMMERCIAL/INDUSTRIAL WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10^-6) (mg/kg)	Noncarcinogens (HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
COPPER	7.7E+03	noncarcinogenic effects	-	7.7E+03	3.8E+04	NA
CYANIDE (Free)	2.5E+03	noncarcinogenic effects	-	2.5E+03	1.2E+04	NA
*DIBENZO(a,h)ANTHTRACENE	3.8E-01	carcinogenic effects	3.8E-01	-	-	NA
*DIBROMOCHLOROMETHANE	2.2E+00	carcinogenic effects	2.2E+00	2.9E+02	1.4E+03	NA
*1,2-DIBROMO-3-CHLOROPROPANE	6.7E-02	carcinogenic effects	6.7E-02	1.9E+00	9.5E+00	1.1E+03
*DIBROMOETHANE, 1,2-	2.5E-01	carcinogenic effects	2.5E-01	2.4E+01	1.2E+02	NA
DICHLOROBENZENE, 1,2-	6.0E+02	saturation limit	-	7.8E+02	3.9E+03	6.0E+02
DICHLOROBENZENE, 1,3-	4.0E+02	noncarcinogenic effects	-	4.0E+02	2.0E+03	6.0E+02
*DICHLOROBENZENE, 1,4-	4.5E+00	carcinogenic effects	4.5E+00	1.7E+03	8.3E+03	NA
*DICHLOROBENZIDINE, 3,3-	1.4E+00	carcinogenic effects	1.4E+00	-	-	NA
*DICHLORODIPHENYLDICHLOROETHANE (DDD)	9.0E+00	carcinogenic effects	9.0E+00	-	-	NA
*DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	6.3E+00	carcinogenic effects	6.3E+00	-	-	NA
*DICHLORODIPHENYLTRICHLOROETHANE (DDT)	6.3E+00	carcinogenic effects	6.3E+00	7.7E+01	3.8E+02	NA
*DICHLOROETHANE, 1,1-	5.9E+00	carcinogenic effects	5.9E+00	3.3E+02	1.7E+03	1.7E+03
*DICHLOROETHANE, 1,2-	7.4E-01	carcinogenic effects	7.4E-01	5.5E+00	2.8E+01	1.8E+03
DICHLOROETHYLENE, 1,1-	8.1E+01	noncarcinogenic effects	-	8.1E+01	4.1E+02	1.5E+03
DICHLOROETHYLENE, Cis 1,2-	2.9E+01	noncarcinogenic effects	-	2.9E+01	1.4E+02	1.2E+03
DICHLOROETHYLENE, Trans 1,2-	4.6E+01	noncarcinogenic effects	-	4.6E+01	2.3E+02	3.1E+03
DICHLOROPHENOL, 2,4-	3.7E+02	noncarcinogenic effects	-	3.7E+02	1.8E+03	NA
*DICHLOROPROPANE, 1,2-	1.4E+00	carcinogenic effects	1.4E+00	3.9E+00	1.9E+01	1.1E+03
*DICHLOROPROPENE, 1,3-	4.6E-01	carcinogenic effects	4.6E-01	3.7E+01	1.8E+02	1.4E+03
*DIELDRIN	1.3E-01	carcinogenic effects	1.3E-01	7.7E+00	3.8E+01	NA
DIETHYLPHTHALATE	9.8E+04	noncarcinogenic effects	-	9.8E+04	4.9E+05	NA
DIMETHYLPHTHALATE	1.2E+06	noncarcinogenic effects	-	1.2E+06	6.2E+06	NA
DIMETHYLPHENOL, 2,4-	7.1E+02	noncarcinogenic effects	-	7.1E+02	3.6E+03	NA
DINITROPHENOL, 2,4-	2.5E+02	noncarcinogenic effects	-	2.5E+02	1.2E+03	NA
*DINITROTOLUENE, 2,4-	5.6E+00	carcinogenic effects	5.6E+00	2.5E+02	1.2E+03	NA
*1,4 DIOXANE	6.4E+01	carcinogenic effects	6.4E+01	1.2E+09	5.8E+09	NA
*DIOXIN (2,3,7,8-TCDD)	1.9E-05	carcinogenic effects	1.9E-05	1.5E+01	7.7E+01	NA
ENDOSULFAN	7.4E+02	noncarcinogenic effects	-	7.4E+02	3.7E+03	NA
ENDRIN	4.6E+01	noncarcinogenic effects	-	4.6E+01	2.3E+02	NA
ETHANOL		not available				
ETHYLBENZENE	4.0E+02	saturation limit	-	2.5E+03	1.2E+04	4.0E+02
FLUORANTHENE	4.4E+03	noncarcinogenic effects	-	4.4E+03	2.2E+04	NA
FLUORENE	3.7E+03	noncarcinogenic effects	-	3.7E+03	1.8E+04	NA
*HEPTACHLOR	5.2E-01	carcinogenic effects	5.2E-01	7.7E+01	3.8E+02	NA
*HEPTACHLOR EPOXIDE	3.1E-01	carcinogenic effects	3.1E-01	1.6E+00	8.0E+00	NA

TABLE K-2. DIRECT-EXPOSURE SCREENING LEVELS
COMMERCIAL/INDUSTRIAL WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10^-6) (mg/kg)	Noncarcinogens (HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
*HEXACHLOROBENZENE	9.6E-01	carcinogenic effects	9.6E-01	9.8E+01	4.9E+02	NA
HEXACHLOROBUTADIENE	2.2E+01	carcinogenic effects	2.2E+01	3.7E+01	1.8E+02	NA
*HEXACHLOROCYCLOHEXANE (gamma) LINDANE	2.0E+00	carcinogenic effects	2.0E+00	4.6E-01	2.3E+02	NA
*HEXACHLOROETHANE	4.4E+01	carcinogenic effects	4.4E+01	1.2E+02	6.2E+02	NA
*INDENO(1,2,3-cd)PYRENE	1.3E+00	carcinogenic effects	1.3E+00	-	-	NA
LEAD	7.5E+02	USEPA Region IX (USEPA 2004)				NA
*MERCURY	3.7E+01	noncarcinogenic effects	-	3.7E+01	1.8E+02	NA
METHOXYCHLOR	7.7E+02	noncarcinogenic effects	-	7.7E+02	3.8E+03	NA
*METHYLENE CHLORIDE	9.2E+00	carcinogenic effects	9.2E+00	1.7E+03	8.3E+03	2.4E+03
METHYL ETHYL KETONE	5.3E+03	noncarcinogenic effects	-	5.3E+03	2.6E+04	3.4E+04
METHYL ISOBUTYL KETONE	5.5E+02	noncarcinogenic effects	-	5.5E+02	2.8E+03	1.7E+04
METHYL MERCURY	1.2E+01	noncarcinogenic effects	-	1.2E+01	6.2E+01	NA
METHYLNAPHTHALENE (total 1- & 2-)	1.3E+03	noncarcinogenic effects	-	1.3E+03	6.5E+03	NA
*METHYL TERT BUTYL ETHER	6.8E+01	carcinogenic effects	6.8E+01	9.8E+03	4.9E+04	2.1E+04
MOLYBDENUM	9.6E+02	noncarcinogenic effects	-	9.6E+02	4.8E+03	NA
NAPHTHALENE	3.8E+00	carcinogenic effects	3.8E+00	1.1E+02	5.4E+02	NA
*NICKEL	1.0E+03	trench/construction worker	2.1E+04	4.1E+03	2.0E+04	NA
*PENTACHLOROPHENOL	1.3E+01	carcinogenic effects	1.3E-01	2.3E+03	1.2E+04	NA
PERCHLORATE	1.9E+01	noncarcinogenic effects	-	1.9E+01	9.6E+01	NA
PHENANTHRENE	3.7E+03	=fluorene	-	3.7E+03	1.8E+04	NA
PHENOL	3.7E+04	noncarcinogenic effects	-	3.7E+04	1.8E+05	NA
*POLYCHLORINATED BIPHENYLS (PCBs)	7.4E-01	carcinogenic effects	7.4E-01	2.1E+00	1.1E+01	NA
PYRENE	3.6E+03	noncarcinogenic effects	-	3.6E+03	1.8E+04	NA
SELENIUM	9.6E+02	noncarcinogenic effects	-	9.6E+02	4.8E+03	NA
SILVER	9.6E+02	noncarcinogenic effects	-	9.6E+02	4.8E+03	NA
STYRENE	1.5E+03	saturation limit	-	3.4E+03	1.7E+04	1.5E+03
tert-BUTYL ALCOHOL	1.5E+02	carcinogenic effects	1.5E+02	-	-	3.2E+05
*TETRACHLOROETHANE, 1,1,1,2-	6.9E+00	noncarcinogenic effects	6.9E+00	3.8E+02	1.9E+03	2.0E+03
*TETRACHLOROETHANE, 1,1,2,2-	8.6E-01	carcinogenic effects	8.6E-01	7.7E+02	3.8E+03	2.0E+03
*TETRACHLOROETHYLENE	1.1E+00	carcinogenic effects	1.1E+00	2.5E+01	1.3E+02	2.3E+02
THALLIUM	1.3E+01	noncarcinogenic effects	-	1.3E+01	6.3E+01	NA
TOLUENE	3.4E+02	noncarcinogenic effects	-	3.4E+02	1.7E+03	6.5E+02
TOXAPHENE	1.8E+00	carcinogenic effects	1.8E+00	-	-	NA
TPH (gasolines)	7.5E+02	noncarcinogenic effects	-	7.5E+02	3.7E+03	4.5E+03
TPH (middle distillates)	7.5E+02	noncarcinogenic effects	-	7.5E+02	3.7E+03	1.5E+02
TPH (residual fuels)	4.6E+03	noncarcinogenic effects	-	4.6E+03	2.3E+04	NA
*TRICHLOROBENZENE, 1,2,4-	4.2E+01	noncarcinogenic effects	4.8E+02	4.2E+01	2.1E+02	NA

TABLE K-2. DIRECT-EXPOSURE SCREENING LEVELS
COMMERCIAL/INDUSTRIAL WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10⁻⁶) (mg/kg)	Noncarcinogens (HQ = 0.2) (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
TRICHLOROETHANE, 1,1,1-	1.2E+03	saturation limit	-	1.4E+03	6.8E+03	1.2E+03
*TRICHLOROETHANE, 1,1,2-	1.5E+00	carcinogenic effects	1.5E+00	2.5E+01	1.2E+02	1.8E+03
**TRICHLOROETHYLENE	6.3E+00	carcinogenic effects	6.3E+00	3.5E+01	1.7E+02	1.3E+03
**TRICHLOROPHENOL, 2,4,5-	2.2E+03	noncarcinogenic effects	-	2.2E+03	1.1E+04	NA
**TRICHLOROPHENOL, 2,4,6-	2.5E+01	carcinogenic effects	2.5E+01	-	-	NA
VANADIUM	1.3E+03	noncarcinogenic effects	-	1.3E+03	6.7E+03	NA
*VINYL CHLORIDE	5.4E-02	carcinogenic effects	5.4E-02	2.8E+01	1.4E+02	1.2E+03
XYLENES	4.2E+02	saturation limit	-	1.2E+03	5.9E+03	4.2E+02
ZINC	5.8E+04	noncarcinogenic effects	-	5.8E+04	2.9E+05	NA

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Primary source: USEPA Region IX Preliminary Remediation Goals (PRGs, USEPA 2004), modified as noted below. See text for discussion.

Notes:

See text for equations and assumptions used in models.

Final screening level is lowest of individual screening levels for carcinogenic effects and noncarcinogenic effects (based on HQ=0.2) or screening level for construction/trench workers if lower (see Table K-3). Saturation limit used as upper limit for volatile organic compounds that are liquid at ambient conditions (see text).

Carcinogens: Based on target cancer risk of 10⁻⁶, modified with respect to CalEPA/OEHHA slope factors when available (marked by **). Screening levels for PCBs based on updated USEPA slope factors as presented in USEPA Region IX Preliminary Remediation Goals document (USEPA 2004).

Noncarcinogens: Adjusted to target hazard quotient of 0.2 for use in tables for all chemicals except TPH (TPH adjusted to HQ of 0.5; see Sections 1.3 and 3.4 in text). Screening levels based on hazard quotient of 1.0 provided for reference.

Saturation: Theoretical soil saturation level in the absence of free product; calculated for volatile organic compounds that are liquids under ambient conditions (refer to Table J).

TPH:Total Petroleum Hydrocarbons. See text for discussion of different TPH categories. Direct exposure screening levels after Massachusetts Department of Environmental Protection (see text).

Direct-exposure screening level for lead from USEPA Region IX Preliminary Remediation Goals document (USEPA 2004).

TABLE K-3. DIRECT-EXPOSURE SCREENING LEVELS
CONSTRUCTION/TRENCH WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10⁻⁶) (mg/kg)	Noncarcinogens HQ = 0.2 (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
ACENAPHTHENE	2.1E+04	noncarcinogenic effects	-	2.1E+04	1.0E+05	NA
ACENAPHTHYLENE	1.5E+04	=fluorene	-	1.5E+04	7.5E+04	NA
ACETONE	1.0E+05	noncarcinogenic effects	-	1.0E+05	5.1E+05	1.0E+05
*ALDRIN	1.5E+00	carcinogenic effects	1.5E+00	1.6E+01	7.8E+01	NA
ANTHRACENE	1.2E+05	noncarcinogenic effects	-	1.2E+05	5.9E+05	NA
ANTIMONY	2.8E+02	noncarcinogenic effects	-	2.8E+02	1.4E+03	NA
*ARSENIC	2.9E+00	carcinogenic effects	2.9E+00	8.2E+01	4.1E+02	NA
BARIUM	2.5E+03	noncarcinogenic effects	-	2.5E+03	1.2E+04	NA
*BENZENE	1.6E+01	carcinogenic effects	1.6E+01	4.0E+02	2.0E+03	8.7E+02
*BENZO(a)ANTHRACENE	1.5E+01	carcinogenic effects	1.5E+01	-	-	NA
*BENZO(b)FLUORANTHENE	1.5E+01	carcinogenic effects	1.5E+01	-	-	NA
*BENZO(k)FLUORANTHENE	1.5E+01	carcinogenic effects	1.5E+01	-	-	NA
BENZO(g,h,i)PERYLENE	1.4E+04	noncarcinogenic effects	-	1.4E+04	7.0E+04	NA
*BENZO(a)PYRENE	1.5E+00	carcinogenic effects	1.5E+00	-	-	NA
*BERYLLIUM	3.6E+01	noncarcinogenic effects	1.1E+02	3.6E+01	1.8E+02	NA
BIPHENYL, 1,1-	1.7E+04	noncarcinogenic effects	-	1.7E+04	8.6E+04	NA
*BIS(2-CHLOROETHYL)ETHER	5.2E+00	carcinogenic effects	5.2E+00	-	-	9.6E+03
BIS(2-CHLOROISOPROPYL)ETHER	1.7E+02	carcinogenic effects	1.7E+02	6.6E+03	3.3E+04	7.9E+02
*BIS(2-ETHYLHEXYL)PHTHALATE	6.4E+03	carcinogenic effects	6.4E+03	8.0E+03	4.0E+04	NA
BORON	4.6E+04	noncarcinogenic effects	-	4.6E+04	2.3E+05	NA
*BROMODICHLOROMETHANE	3.2E+01	carcinogenic effects	3.2E+01	1.7E+03	8.3E+03	3.0E+03
BROMOFORM	2.6E+03	carcinogenic effects	2.6E+03	8.0E+03	4.0E+04	NA
BROMOMETHANE	3.0E+01	noncarcinogenic effects	-	3.0E+01	1.5E+02	3.1E+03
*CADMIUM	3.8E+01	carcinogenic effects	3.8E+01	8.2E+01	4.1E+02	NA
*CARBON TETRACHLORIDE	8.2E+00	carcinogenic effects	8.2E+00	1.5E+02	7.3E+02	1.1E+03
*CHLORDANE	2.1E+01	carcinogenic effects	2.1E+01	2.6E+02	1.3E+03	NA
CHLOROANILINE, p-	1.6E+03	noncarcinogenic effects	-	1.6E+03	8.0E+03	NA
CHLOROBENZENE	6.8E+02	saturation limit	-	1.2E+03	5.8E+03	6.8E+02
CHLOROETHANE	2.8E+02	carcinogenic effects	2.8E+02	3.7E+04	1.9E+05	1.6E+03
*CHLOROFORM	7.8E+01	carcinogenic effects	7.8E+01	4.2E+02	2.1E+03	2.9E+03
CHLOROMETHANE	2.8E+01	carcinogenic effects	2.8E+01	1.3E+03	6.4E+03	4.1E+03
CHLOROPHENOL, 2-	4.7E+02	noncarcinogenic effects	-	4.7E+02	2.3E+03	5.5E+04
CHROMIUM (Total)	-	-	-	-	-	NA
CHROMIUM III	1.1E+06	noncarcinogenic effects	-	1.1E+06	5.3E+06	NA
*CHROMIUM VI	1.8E+00	carcinogenic effects	1.8E+00	4.0E+01	2.0E+02	NA
*CHRYSENE	1.5E+02	carcinogenic effects	1.5E+02	-	-	NA
COBALT	1.0E+01	noncarcinogenic effects	9.4E+01	1.0E+01	5.2E+01	NA

TABLE K-3. DIRECT-EXPOSURE SCREENING LEVELS
CONSTRUCTION/TRENCH WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10⁻⁶) (mg/kg)	Noncarcinogens HQ = 0.2 (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
COPPER	2.8E+04	noncarcinogenic effects	-	2.8E+04	1.4E+05	NA
CYANIDE (Free)	8.2E+03	noncarcinogenic effects	-	8.2E+03	4.1E+04	NA
*DIBENZO(a,h)ANTHTRACENE	4.3E+00	carcinogenic effects	4.3E+00	-	-	NA
*DIBROMOCHLOROMETHANE	7.3E+01	carcinogenic effects	7.3E+01	2.7E+03	1.4E+04	NA
1,2-DIBROMO-3-CHLOROPROPANE	1.7E+00	carcinogenic effects	1.7E+00	1.4E+01	6.8E+01	1.1E+03
*DIBROMOETHANE, 1,2-	4.6E+00	carcinogenic effects	4.6E+00	2.8E+02	1.4E+03	NA
DICHLOROBENZENE, 1,2-	6.0E+02	saturation limit	-	8.2E+03	4.1E+04	6.0E+02
DICHLOROBENZENE, 1,3-	6.0E+02	saturation limit	-	3.8E+03	1.9E+04	6.0E+02
*DICHLOROBENZENE, 1,4-	1.9E+02	carcinogenic effects	1.9E+02	9.2E+03	4.6E+04	NA
*DICHLOROBENZIDINE, 3,3-	1.7E+01	carcinogenic effects	1.7E+01	-	-	NA
*DICHLORODIPHENYLDICHLOROETHANE (DDD)	1.1E+02	carcinogenic effects	1.1E+02	-	-	NA
*DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	7.6E+01	carcinogenic effects	7.6E+01	-	-	NA
*DICHLORODIPHENYLTRICHLOROETHANE (DDT)	7.6E+01	carcinogenic effects	7.6E+01	2.6E+02	1.3E+03	NA
*DICHLOROETHANE, 1,1-	2.5E+02	carcinogenic effects	2.5E+02	3.9E+03	1.9E+04	1.7E+03
*DICHLOROETHANE, 1,2-	3.1E+01	carcinogenic effects	3.1E+01	6.9E+01	3.4E+02	1.8E+03
*DICHLOROETHYLENE, 1,1-	9.8E+02	noncarcinogenic effects	-	9.8E+02	4.9E+03	1.5E+03
*DICHLOROETHYLENE, Cis 1,2-	3.4E+02	noncarcinogenic effects	-	3.4E+02	1.7E+03	1.2E+03
*DICHLOROETHYLENE, Trans 1,2-	5.5E+02	noncarcinogenic effects	-	5.5E+02	2.7E+03	3.1E+03
DICHLOROPHENOL, 2,4-	1.2E+03	noncarcinogenic effects	-	1.2E+03	6.0E+03	NA
*DICHLOROPROPANE, 1,2-	4.5E+01	noncarcinogenic effects	5.7E-01	4.5E+01	2.2E+02	1.1E+03
*DICHLOROPROPENE, 1,3-	1.9E+01	carcinogenic effects	1.9E+01	4.4E+02	2.2E+03	1.4E+03
*DIELDRIN	1.6E+00	carcinogenic effects	1.6E+00	2.6E+01	1.3E+02	NA
DIETHYLPHTHALATE	3.2E+05	noncarcinogenic effects	-	3.2E+05	1.6E+06	NA
DIMETHYLPHTHALATE	4.0E+06	noncarcinogenic effects	-	4.0E+06	2.0E+07	NA
DIMETHYLPHENOL, 2,4-	4.9E+03	noncarcinogenic effects	-	4.9E+03	2.5E+04	NA
DINITROPHENOL, 2,4-	8.0E+02	noncarcinogenic effects	-	8.0E+02	4.0E+03	NA
*DINITROTOLUENE, 2,4-	6.4E+01	carcinogenic effects	6.4E+01	8.0E+02	4.0E+03	NA
*1,4 DIOXANE	7.4E+02	carcinogenic effects	7.4E+02	1.6E+07	7.9E+07	NA
*DIOXIN (2,3,7,8-TCDD)	2.4E-04	carcinogenic effects	2.4E-04	2.1E-01	1.0E+00	NA
ENDOSULFAN	2.4E+03	noncarcinogenic effects	-	2.4E+03	1.2E+04	NA
ENDRIN	1.6E+02	noncarcinogenic effects	-	1.6E+02	7.8E+02	NA
ETHANOL		not available				
ETHYLBENZENE	4.0E+02	saturation limit	-	2.0E+04	1.0E+05	4.0E+02
FLUORANTHENE	1.4E+04	noncarcinogenic effects	-	1.4E+04	7.0E+04	NA
FLUORENE	1.5E+04	noncarcinogenic effects	-	1.5E+04	7.5E+04	NA
*HEPTACHLOR	6.3E+00	carcinogenic effects	6.3E+00	2.6E+02	1.3E+03	NA
*HEPTACHLOR EPOXIDE	3.6E+00	carcinogenic effects	3.6E+00	5.2E+00	2.6E+01	NA

TABLE K-3. DIRECT-EXPOSURE SCREENING LEVELS
CONSTRUCTION/TRENCH WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10^{-6}) (mg/kg)	Noncarcinogens HQ = 0.2 (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
*HEXACHLOROBENZENE	1.1E+01	carcinogenic effects	1.1E+01	3.2E+02	1.6E+03	NA
HEXACHLOROBUTADIENE	1.2E+02	noncarcinogenic effects	2.6E+02	1.2E+02	6.0E+02	NA
*HEXACHLOROCYCLOHEXANE (gamma) LINDANE	2.4E+01	carcinogenic effects	2.4E+01	1.6E+02	7.8E+02	NA
*HEXACHLOROETHANE	4.0E+02	noncarcinogenic effects	5.1E+02	4.0E+02	2.0E+03	NA
*INDENO(1,2,3-cd)PYRENE	1.5E+01	carcinogenic effects	1.5E+01	-	-	NA
LEAD	7.5E+02	=occupational				NA
MERCURY	9.8E+01	noncarcinogenic effects	-	9.8E+01	4.9E+02	NA
METHOXYCHLOR	2.6E+03	noncarcinogenic effects	-	2.6E+03	1.3E+04	NA
*METHYLENE CHLORIDE	3.4E+02	carcinogenic effects	3.4E+02	1.3E+04	6.4E+04	2.4E+03
METHYL ETHYL KETONE	3.4E+04	saturation limit	-	5.5E+04	2.8E+05	3.4E+04
METHYL ISOBUTYL KETONE	6.0E+03	noncarcinogenic effects	-	6.0E+03	3.0E+04	1.7E+04
METHYL MERCURY	4.1E+01	noncarcinogenic effects	-	4.1E+01	2.0E+02	NA
METHYLNAPHTHALENE (total 1- & 2-)	9.4E+03	noncarcinogenic effects	-	9.4E+03	4.7E+04	NA
*METHYL TERT BUTYL ETHER	2.5E+03	carcinogenic effects	2.5E+03	9.8E+04	4.9E+05	2.1E+04
MOLYBDENUM	3.6E+03	noncarcinogenic effects	-	3.6E+03	1.8E+04	NA
NAPHTHALENE	9.7E+01	carcinogenic effects	9.7E+01	1.2E+03	6.0E+03	NA
*NICKEL	1.0E+03	carcinogenic effects	1.0E+03	1.5E+04	7.7E+04	NA
*PENTACHLOROPHENOL	1.5E+02	carcinogenic effects	1.5E+02	7.1E+03	3.5E+04	NA
PERCHLORATE	7.1E+01	noncarcinogenic effects	-	7.1E+01	3.6E+02	NA
PHENANTHRENE	1.5E+04	=fluorene	-	1.5E+04	7.5E+04	NA
PHENOL	1.2E+05	noncarcinogenic effects	-	1.2E+05	6.0E+05	NA
*POLYCHLORINATED BIPHENYLS (PCBs)	6.7E+00	noncarcinogenic effects	8.4E+00	6.7E+00	3.4E+01	NA
PYRENE	1.2E+04	noncarcinogenic effects		1.2E+04	6.1E+04	NA
SELENIUM	3.4E+03	noncarcinogenic effects		3.4E+03	1.7E+04	NA
SILVER	3.6E+03	noncarcinogenic effects		3.6E+03	1.8E+04	NA
STYRENE	1.5E+03	saturation limit		3.1E+04	1.5E+05	1.5E+03
tert-BUTYL ALCOHOL	3.7E+03	carcinogenic effects	3.7E+03	-	-	3.2E+05
*TETRACHLOROETHANE, 1,1,1,2-	2.4E+02	carcinogenic effects	2.4E+02	3.7E+03	1.9E+04	2.0E+03
*TETRACHLOROETHANE, 1,1,2,2-	2.8E+01	carcinogenic effects	2.8E+01	7.4E+03	3.7E+04	2.0E+03
*TETRACHLOROETHYLENE	2.5E+01	carcinogenic effects	2.5E+01	3.0E+02	1.5E+03	2.3E+02
THALLIUM	4.7E+01	noncarcinogenic effects		4.7E+01	2.3E+02	NA
TOLUENE	6.5E+02	saturation limit		4.1E+03	2.0E+04	6.5E+02
TOXAPHENE	2.2E+01	carcinogenic effects	2.2E+01	-	-	NA
TPH (gasolines)	6.0E+03	noncarcinogenic effects		6.0E+03	3.0E+04	NA
TPH (middle distillates)	6.0E+03	noncarcinogenic effects		6.0E+03	3.0E+04	NA
TPH (residual fuels)	1.5E+04	noncarcinogenic effects		1.5E+04	7.5E+04	NA
**TRICHLOROBENZENE, 1,2,4-	4.8E+02	noncarcinogenic effects	5.7E+03	4.8E+02	2.4E+03	NA

TABLE K-3. DIRECT-EXPOSURE SCREENING LEVELS
CONSTRUCTION/TRENCH WORKER EXPOSURE SCENARIO

CHEMICAL	Final Screening Level (mg/kg)	Basis	Carcinogens (Risk = 10⁻⁶) (mg/kg)	Noncarcinogens HQ = 0.2 (mg/kg)	Noncarcinogens (HQ = 1.0) (mg/kg)	Saturation (mg/kg)
TRICHLOROETHANE, 1,1,1-	1.2E+03	saturation limit	-	1.5E+04	7.6E+04	1.2E+03
*TRICHLOROETHANE, 1,1,2-	5.7E+01	carcinogenic effects	5.7E+01	2.7E+02	1.4E+03	1.8E+03
*TRICHLOROETHYLENE	1.2E+02	noncarcinogenic effects	2.5E+02	1.2E+02	6.0E+02	1.3E+03
TRICHLOROPHENOL, 2,4,5-	1.9E+04	noncarcinogenic effects	-	1.9E+04	9.3E+04	NA
*TRICHLOROPHENOL, 2,4,6-	2.9E+02	carcinogenic effects	2.9E+02	-	-	NA
VANADIUM	5.0E+03	noncarcinogenic effects	-	5.0E+03	2.5E+04	NA
*VINYL CHLORIDE	2.4E+00	carcinogenic effects	2.4E+00	2.9E+02	1.4E+03	1.2E+03
XYLENES	4.2E+02	saturation limit	-	1.3E+04	6.5E+04	4.2E+02
ZINC	2.1E+05	noncarcinogenic effects	-	2.1E+05	1.1E+06	NA

Red: >25% change in comparison to July 2003 ESL. Ethanol added to February 2005 ESLs

Primary source: USEPA Region IX Preliminary Remediation Goals (PRGs, USEPA 2004), modified as noted below. See text for discussion.

Notes:

See text for equations and assumptions used in models.

Final screening level is lowest of individual screening levels for carcinogenic effects and noncarcinogenic effects (based on HQ=0.2) or screening level for construction/trench workers if lower (see Table K-3). Saturation limit used as upper limit for volatile organic compounds that are liquid at ambient conditions (see text).

Carcinogens: Based on target cancer risk of 10⁻⁶, modified with respct to CalEPA/OEHHA slope factors when available (marked by "**"). Screening levels for PCBs based on updated USEPA slope factors as presented in USEPA Region IX Preliminary Remediation Goals document (USEPA 2004).

Noncarcinogens: Adjusted to target hazard quotient of 0.2 for use in tables for all chemicals except TPH (TPH adjusted to HQ of 0.5; see Sections 1.3 and 3.4 in text). Screening levels based on hazard quotient of 1.0 provided for reference.

Saturation: Theoretical soil saturation level in the absence of free product; calculated for volatile organic compounds that are liquids under ambient conditions (refer to Table J).

TPH:Total Petroleum Hydrocarbons. See text for discussion of different TPH categories. Direct exposure screening levels after Massachusetts Department of Environmental Protection (see text).

TABLE L. TARGET ORGANS AND CHRONIC HEALTH EFFECTS

(For general reference only. May not be adequately comprehensive for some chemicals.
Some noted effects may be insignificant. Refer to original documents for additional information.)

CHEMICAL PARAMETER	Carcinogen°	Alimentary Tract a	Cardiovascular	Developmental	Endocrine	Eye	Hematologic	Immune	Kidney	Nervous	Reproductive	Respiratory	Skin°	Other
ACENAPHTHENE	NA	5,6						4					4	
ACENAPHTHYLENE	D						5,6	4					4	= Fluorene
ACETONE	D	5,6					3		5,6					
ALDRIN	B2	6								3				
ANTHRACENE	D					3,4		4					4	
ANTIMONY	D		4				5,7				4	1,3,4		hair loss (4)
ARSENIC	A	3,4,6	1,2,4	1,2,3,4			3,4,6			1,2,3,4	4		1,3,4,6	
BARIUM	D		4				5		6		5			hypertension (6)
BENZENE	A	3		1,2,4			1,2,3,4	3		1,2			4	
BENZO(a)ANTHRACENE	B2							4					4	No chronic toxicity factors.
BENZO(b)FLUORANTHENE	B2							4					4	No chronic toxicity factors.
BENZO(k)FLUORANTHENE	B2							4					4	No chronic toxicity factors.
BENZO(g,h,i)PERYLENE	D	5,6					5,6	4	5,6				4	= Fluoranthene
BENZO(a)PYRENE	B2							4			3		4	No chronic toxicity factors.
BERYLLIUM	B1	1,6						2	1			1,2,3,4,6	3	
BIPHENYL, 1,1-	D	3							6	3				
BIS(2-CHLOROETHYL)ETHER	B2									4	4			
BIS(2-CHLOROISOPROPYL)ETHER	NA						6							No chronic toxicity factors.
BIS(2-ETHYLHEXYL)PHTHALATE	NA	7												No chronic toxicity factors.
BORON	D								4,6		4,6	5		
BROMODICHLOROMETHANE	B2	4							4,6					
BROMOFORM	B2	3,4,6							4	3,4				
BROMOMETHANE	D	3,5,6		1,2					3,4	1,2,3,4		1,2,3,4,6		
CADMIUM	B1/D	1,2,4,6							1,2,3,4,5,6	1,2,3,4		1,2,3,4		bone loss (1,4)
CARBON TETRACHLORIDE	B2	1,2,4,6		1,2					4	1,2				
CHLORDANE	B2	3,4,6						3,5		4				
CHLOROANILINE, p-	NA	3,6						5	3					
CHLOROBENZENE	D	1,2,3,5,6					3		1,2,3,4,5	3	1,2		3	
CHLOROETHANE	B	1,2		1,2,4										
CHLOROFORM	B2	1,2,3,4,6		1,2					1,2,3,4					
CHLOROMETHANE	C/D			4						3	3,4			
CHLOROPHENOL, 2-	D	1,4		1							1,5,6			
CHROMIUM (Total)	-													
CHROMIUM III	D												3	
CHROMIUM VI	A						1	4				1,6	4	
CHRYSENE	B2										2		4	No chronic toxicity factors.
COBALT	NA		3									3	3	hearing (3)
COPPER	D											1,4	3	
CYANIDE (Free)	D		1,4		1,4,6					1,5,6		4		
DIBENZO(a,h)ANTHRACENE	B2							4					3,4	
DIBROMOCHLOROMETHANE	C	6												
1,2-DIBROMO-3-CHLOROPROPANE		1		1					3		1,3,4,5,6	1		
DIBROMOETHANE, 1,2-	B2			4							4	1,3		

TABLE L. TARGET ORGANS AND CHRONIC HEALTH EFFECTS

(For general reference only. May not be adequately comprehensive for some chemicals. Some noted effects may be insignificant. Refer to original documents for additional information.)

CHEMICAL PARAMETER	Carcinogen	Alimentary Tract	Cardiovascular	Developmental	Endocrine	Eye	Hematologic	Immune	Kidney	Nervous	Reproductive	Respiratory	Skin	Other
DICHLOROBENZENE, 1,2-	D	3							3				3	
DICHLOROBENZENE, 1,3-	D	3							3					
DICHLOROBENZENE, 1,4-	C	1,2,3,6					3		1,2,3	1,2	6	1,2		
DICHLOROBENZIDINE, 3,3-	B2	3												No chronic toxicity factors.
DICHLORODIPHENYLDICHLOROETHANE (DDD)	B2													No chronic toxicity factors.
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	B2													No chronic toxicity factors.
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	B2	3,4,6							3,4,5,7	3	3			
DICHLOROETHANE, 1,1-	C	3												
DICHLOROETHANE, 1,2-	B2	1,2												
DICHLOROETHYLENE, 1,1-	C/D	1,2,3,4,5,6					4,5,7		3	4		4		
DICHLOROETHYLENE, Cis 1,2-	D	4												
DICHLOROETHYLENE, Trans 1,2-	D	4					5,6					4		
DICHLOROPHENOL, 2,4-	E							5						
DICHLOROPROPANE, 1,2-	B2	3					3					5		
DICHLOROPROPENE, 1,3-	B2	6										4		
DIELDRIN	B2	6								3				
DIETHYLPHTHALATE	D			6							4			
DIMETHYLPHTHALATE	D													
DIMETHYLPHENOL, 2,4-	NA						5,6			5,6				
DINITROPHENOL, 2,4-	NA					3,6				3				
DINITROTOLUENE, 2,4-	B2						3			3,6				
1,4 DIOXANE	B2	1,2	3						1,2					
DIOXIN (2,3,7,8-TCDD)	NA	1,2,4	1,2	1,2,4	1,2,4		1,2	4	4,5,6	4,6	1,2,4	1,2,4	4	No chronic toxicity factors.
ENDOSULFAN	NA	4		4,6			6	4	4,5,6	4,6	4			
ENDRIN	D	5,6		4					6	5				
ETHANOL														No chronic toxicity factors.
ETHYLBENZENE	D	1,2,5,6		1,2,4,6	1,2				1,2,5,6	3	3		3	
FLUORANTHENE	D	5,6					5,6	4	5,6		4		4	
FLUORENE	D						5,6	4					4	
HEPTACHLOR	B2	6												
HEPTACHLOR EPOXIDE	B2	6								7				
HEXACHLOROBENZENE	B2	1,3,4,6			4			4	4	3,4	3			bones (4)
HEXACHLOROBUTADIENE	C	4							4				3	
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NA	1,3,6							1,3,6					
HEXACHLOROETHANE	C	3,4							3,4,6					
INDENO(1,2,3-cd)PYRENE	B2							4						No chronic toxicity factors.
LEAD	B2	3,7	7	3,7			3,7	3,7	3,7	3,7	7		4	
MERCURY	D			4				1	1,3	1,2,3,5,6				
METHOXYCHLOR	D	3		6					3	3	3,5,6			
METHYLENE CHLORIDE	B2	3,6	1,2						3	1,2				
METHYL ETHYL KETONE	D			6							1,3			
METHYL ISOBUTYL KETONE	NA			6						7				
METHYL MERCURY	C			6						1,6				

TABLE L. TARGET ORGANS AND CHRONIC HEALTH EFFECTS

(For general reference only. May not be adequately comprehensive for some chemicals.
Some noted effects may be insignificant. Refer to original documents for additional information.)

CHEMICAL PARAMETER	Carcinogen[a]	Target Organs And Health Effects												
		Alimentary Tract[b]	Cardiovascular	Developmental	Endocrine	Eye	Hematologic	Immune	Kidney	Nervous	Reproductive	Respiratory	Skin[c]	Other
METHYLNAPHTHALENE (total 1- & 2-)	C						5,6	4					4	= Fluorene
METHYL TERT BUTYL ETHER	NA	1,2,6				1,2			1,2,6					
MOLYBDENUM	D						6							
NAPHTHALENE	B2					3	3	4				1,2,6	4	
NICKEL	A/D	1,6					1,2	4	6			1,2,3	3	
PENTACHLOROPHENOL	B2	1,3,4,6		1,4			4	4	3,6	3,4	1	3,4		
PERCHLORATE					8									
PHENANTHRENE	D						3	4					4	= Fluorene
PHENOL	D	1,2,3	1,2	4,6		6	5,6		1,2,3	1,2	5		4	
POLYCHLORINATED BIPHENYLS (PCBs)	B2	1,3,4		1,4	4		4	1,4,6			1,3,4			
PYRENE	D							4	5,6					
SELENIUM	D	1,2,3,6	1,2				6			1,2		1,3	3,4,6	Selenosis (4,6)
SILVER	D												3,4,6	
STYRENE	C	4,5,6					5,6			1,2,3,5,6		3	3	
tert-BUTYL ALCOHOL														No chronic toxicity factors.
TETRACHLOROETHANE, 1,1,1,2-	C	6							6					
TETRACHLOROETHANE, 1,1,2,2-	C	3,4								3,4				
TETRACHLOROETHYLENE	NA	1,2,3,6							1,2,3					
THALLIUM	D	3	3			3	6			3,4	3,4		3	
TOLUENE	D	5,6		1,2,4					5,6	1,2,3,6	3	1,2,6		
TOXAPHENE	B2	4			4			4	4					
TPH (gasolines)	-													
TPH (middle distillates)	-													
TPH (residual fuels)	-													
TRICHLOROBENZENE, 1,2,4-	D				5,6									
TRICHLOROETHANE, 1,1,1-	D	3,7								1,2				
TRICHLOROETHANE, 1,1,2-	C	6											3	
TRICHLOROETHYLENE	B2	3,4,7		4,7		1,2	7	7	3,4,7	1,2,3,4				
TRICHLOROPHENOL, 2,4,5-	NA	1,3,5,6		1					3,5,6		1			
TRICHLOROPHENOL, 2,4,6-	B2	3												
VANADIUM	D	4							4			3,4		

TABLE L. TARGET ORGANS AND CHRONIC HEALTH EFFECTS

(For general reference only. May not be adequately comprehensive for some chemicals. Some noted effects may be insignificant. Refer to original documents for additional information.)

CHEMICAL PARAMETER	Carcinogen[a]	Alimentary Tract[b]	Cardiovascular	Developmental	Endocrine	Eye	Hematologic	Immune	Kidney	Nervous	Reproductive	Respiratory	Skin[c]	Other
VINYL CHLORIDE	A	1,3,4,6		1,4			3,4	4		4	1,4		3	No chronic toxicity factors.
XYLENES	D									1,2,3,4,5,6		1,2		
ZINC	D		1		4		1,2,4,5,6					1		

Notes:

a. Carcinogen type from RWQCBCV 2001; ORNL 2001 (see classification below).

b. Includes gastro-intestinal tract, liver, spleen, gall bladder, etc.

c. Includes skin sensitization but not general dermatitis or defatting of skin.

Perchlorate: Chronic effects as summarized in California DHS Perchlorate Action Level supporting document (CalDHS 2001).

Carcinogen Classification

A: Human carcinogen

B: Probable human carcinogen (B1: limited human evidence; B2 Sufficient evidence in animals and inadequate or no evidence in humans)

C: Possible human carcinogen

D: Not classifiable as to human carcinogenicity

E: Evidence of noncarcinogenicity for humans

NA: Carcinogen classification information not available

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APPENDIX 2

EQUATIONS FOR DERIVATION OF ENVIRONMENTAL SCREENING LEVELS FOR SOIL (DIRECT EXPOSURE), INDOOR AIR AND DRINKING WATER

EQUATIONS FOR DERIVATION OF RISK-BASED SCREENING LEVELS FOR SOIL, INDOOR AIR AND DRINKING WATER

1.0 Introduction

A summary of models and assumptions used to develop screening levels for human health, direct-exposure concerns is presented below. For addition information on the models refer to the document *Region IX Preliminary Remediation Goals* ("PRGs", USEPA 2004) and other documents as referenced. A copy of the text of this document is attached.

2.0 SOIL

2.1 Shallow Soils

Human exposure assumptions are summarized in Table 1. With the exception of the construction/trench worker exposure scenario, parameter values in Table 1 were taken directly from the USEPA Region IX PRG document. Parameter values for the construction/trench worker exposure scenario are discussed in more detail in Appendix 1. Tables 2 and 3 summarize equations and parameter values used to develop the PRG Volatilization Factors and Particulate Emission Factor.

Age-Adjusted Exposure Factors

Carcinogenic risks under residential exposure scenarios were calculated using the following age-adjusted factors:

1) ingestion [(mg-yr)/kg-day)]:

$$IFS_{adj} = \frac{ED_c \ x \ IRS_c}{BW_C} + \frac{(ED_r - ED_c) \ x \ IRS_a}{BW_a}$$

2) dermal contact [(mg-yr)/kg-day)]:

$$SFS_{adj} = \frac{ED_c \ x \ AF_c \ x \ SA_c}{BW_C} + \frac{(ED_r - ED_c) \ x \ AF_a \ x \ IRS_a}{BW_a}$$

3) inhalation [(m3-yr)/kg-day)]:

$$InhF_{adj} = \frac{ED_c \ x \ IRA_c}{BW_C} + \frac{(ED_r - ED_c) \ x \ IRA_a}{BW_a}$$

Definition of terms and default parameter values used in the equations are presented in Tables a through c.

Direct exposure equations for soil are summarized as follows:

Equation 1: Combined Exposures to Carcinogenic Contaminants in Residential Soil

$$C(mg/kg) = \frac{TR \times AT_c}{EF_r \left[\left(\dfrac{IFS_{adj} \times CSF_o}{10^6 mg/kg}\right) + \left(\dfrac{SF_{adj} \times ABS \times CSF_o}{10^6 mg/kg}\right) + \left(\dfrac{InhF_{adj} \times CSF_i}{VF}\right)\right]}$$

Equation 2: Combined Exposures to Noncarcinogenic Contaminants in Residential Soil

$$C(mg/kg) = \frac{THQ \times BW_c \times AT_n}{EF_r \times ED_c \left[\left(\dfrac{I}{RfD_o} \times \dfrac{IRS_c}{10^6 mg/kg}\right) + \left(\dfrac{I}{RfD_o} \times \dfrac{SA_c \times AF_c \times ABS}{10^6 mg/kg}\right) + \left(\dfrac{I}{RfD_i} \times \dfrac{IRA_c}{VF}\right)\right]}$$

Equation 3: Combined Exposures to Carcinogenic Contaminants in Industrial Soil

$$C(mg/kg) = \frac{TR \times BW_a \times AT_c}{EF_o \times ED_o \left[\left(\dfrac{IRS_o \times CSF_o}{10^6 mg/kg}\right) + \left(\dfrac{SA_a \times AF_a \times ABS \times CSF_o}{10^6 mg/kg}\right) + \left(\dfrac{IRA_a \times CSF_i}{VF}\right)\right]}$$

Equation 4: Combined Exposures to Noncarcinogenic Contaminants in Industrial Soil

$$C(mg/kg) = \frac{THQ \times BW_a \times AT_n}{EF_o \times ED_o \left[\left(\dfrac{I}{RfD_o} \times \dfrac{IRS_o}{10^6 mg/kg}\right) + \left(\dfrac{I}{RfD_o} \times \dfrac{SA_a \times AF_a \times ABS}{10^6 mg/kg}\right) + \left(\dfrac{I}{RfD_i} \times \dfrac{IRA_a}{VF}\right)\right]}$$

Equation 5: Derivation of the Volatilization Factor

$$VF(m^3/kg) = (Q/C) \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times P_b \times D_A)} \times 10^{-4}(m^2/cm^2)$$

$$D_A = \frac{\left[\left(\Theta_a^{10/3} D_i H^i + \Theta_w^{10/3} D_w\right)/n^2\right]}{P_b K_d + \Theta_w + \Theta_a H'}$$

Equation 6: Derivation of the Soil Saturation Limit

$$sat = \frac{S}{P_b}\left(K_d P_b + \Theta_w + H'\Theta_a\right)$$

Equation 7: Derivation of the Particulate Emission Factor (residential and occupation exposures)

$$\text{PEF}(\text{m}^3/\text{kg}) \quad = \quad Q/C \text{ x } \frac{3600\text{s}/\text{h}}{0.036 \times (1-V)(U_m/U_t)^3 \times F(x)}$$

Volatilization factors (VF) are used for volatile chemicals (defined as having a Henry's Law Constant (atm-m3/mol) greater than 10-5 and a molecular weight less than 200 grams/mol. The VF term in the soil equations is replaced in the equations with a Particulate Emission Factor (PEF) for non-volatile chemicals.

Use of the Volatilization Factor equation to predict vapor-phase concentrations of a chemical in air is not valid if free-product is present. In cases where a chemicals direct-contact screening level exceeds the chemicals theoretical saturation level, and the chemical is a liquid under ambient conditions, the direct-contact screening level is replaced with the chemicals saturation limit.

2.2   Deep Soils

Direct-exposure screening levels for deep soils are calculated based on a construction/trench worker exposure scenario. Exposure assumptions are summarized in Table 1.   The assumed exposed skin area and soil ingestion rate are based on guidance presented in the USEPA *Exposure Factor handbook* (USEPA 1997). The inhalation rate, body weight, averaging time and target hazard quotient are set equal to assumptions used in the USEPA Region IX *Preliminary Remediation Goals* (USEPA 2004) for consistency with screening levels for occupational exposure assumptions. The soil adherence factor is taken from trench-worker exposure scenario assumptions developed by the Massachusetts Department of Environmental Protection for use in calculating screening levels for Deep soils (MADEP 1994).

The Massachusetts Department of Environmental Protection assumes exposure durations of three months for noncarcinogens (plus use of subchronic RfDs) and seven years for carcinogens. A seven year (versus three month) exposure duration for carcinogens is used in part because shorter exposure durations were considered to be beyond the limits of cancer risk models. For the purposes of this document, a one-time, three month exposure duration to exposed soils at a site was considered to be inadequate. This may be particularly true for utility workers who re-visit a site numerous times over several years for routine maintenance of underground utilities.   As noted in Table 1, a total exposure duration of seven years is assumed for both carcinogens and noncarcinogens. An exposure frequency of 20 days (4 weeks) per year for 7 years yields a total of 140 days total exposure. Construction workers may receive 140 days (roughly 6 months) of exposure in a single year and never visit the site again. Using chronic RfDs (generally less stringent that subchronic RfDs) and spreading the total exposure time over seven years is somewhat conservative but is consistent with the utility worker scenario. A target risk of 1E-06 was used to calculate soil screening levels for carcinogens. A target hazard quotient of 0.2 was used to calculate soil screening levels for noncarcinogens. This is consistent with assumption used to develop screening levels for residential and industrial/commercial exposure scenarios.

"Particulate Emission Factors (PEF)" are intended to relate the concentration of a chemical in soil to the concentration of the chemical in air-born dust. The PEF used for residential and occupational exposure scenarios (1.316E+09 mg-kg/mg/m^3) was taken directly from the USEPA *Region IX Preliminary Remediation Goals* guidance document (USEPA 2004). The PEF reflects a concentration of air-born particulate matter of approximately 0.76 ug/m^3. This PEF and associated concentration of air-born dust was not considered to be adequately conservative of conditions that may occur at construction sites.   A revised PEF for this exposure scenario was derived through use of a "Dust Emission Factor" for construction sites developed by the USEPA. The Dust Emission Factor of 1.2 tons of dust per month, per acre is based on USEPA field studies at apartment complex and commercial center developments in semi-

arid areas (USEPA 1974, 1985). Derivation of the construction-site PEF is summarized in Table 4. The derived PEF (1.44E+06 mg-kg/mg/m^3) corresponds to a concentration of air-born dust of approximately 700 ug/m^3.

3.0 INDOOR AIR

Target levels for indoor air were calculated based on equations incorporated into vapor intrusion spreadsheets published by the USEPA (USEPA 2003):

Equation 8: Residential Exposures to Carcinogenic Contaminants in Indoor Air

$$C_{air}(ug/m^3) = \frac{TR \ x \ AT_c}{EF_{res} \ x \ ED_{res} x \ URF}$$

Equation 9: Occupational Exposures to Carcinogenic Contaminants in Indoor Air

$$C_{air}(ug/m^3) = \frac{TR \ x \ AT_c}{EF_{occ} \ x \ ED_{occ} x \ URF}$$

Equation 10: Residential Exposures to Noncarcinogenic Contaminants in Indoor Air

$$C_{air}(ug/m^3) = \frac{THQ \ x \ AT_{nc} x \ RfC}{EF_{res} \ x \ ED_{res}}$$

Equation 11: Occupational Exposures to Noncarcinogenic Contaminants in Indoor Air

$$C_{air}(ug/m^3) = \frac{THQ \ x \ AT_{nc} x \ RfC}{EF_{occ} \ x \ ED_{occ}}$$

where URF is the unit risk factor carcinogens (ug/m3)$^{-1}$ for and RfC carcinogens (ug/m3) is the reference concentration for noncarcinogens. A summary of URFs and RfCs for specific chemicals is provided in Table E-3 of Appendix 1.

4.0 DRINKING WATER

Equations for calculation of risk-based drinking water goals are taken from Central Valley Water Board technical document *A Compilation of Water Quality Goals* (RWQCBCV 2000). Default parameter values are noted in Table 1.

Equation 12: Ingestion of Carcinogenic Contaminants in Drinking Water

$$C(ug/L) = \frac{TR \times 70kg}{CSF \times 2L/d} \times 1000ug/mg$$

Equation 13: Ingestion of Noncarcinogenic Contaminants in Drinking Water

$$C(ug/L) = \frac{RfD \times 70kg}{2L/d} \times \frac{RSC}{UF} \times 1000ug/mg$$

where RSC is the Relative Contribution Factor (default is 20% or 0.2) and UF is an additional uncertainty factor of 10 that is included for Class C carcinogens when no cancer slope factor has been developed.

USEPA Region IX PRGs offer an alternative model for volatile chemicals that takes into account inhalation of vapors during showering and other activities (USEPA 2004):

Equation 14: Ingestion and Inhalation of Carcinogenic Contaminants in Tapwater

$$C(ug/L) = \frac{TR \times ATc}{EFr[(IFWadj \times CSFo) + (VFw \times InhFadj \times CSFi)]} \times 1000ug/mg$$

Equation 15: Ingestion and Inhalation of Noncarcinogenic Contaminants in Tapwater

$$C(ug/L) = \frac{THQ \times BWa \times ATn}{EFr \times EDr\left[\left(\dfrac{IRWa}{RfDo}\right) + \left(\dfrac{VFw + IRAa}{RfDi}\right)\right]} \times 1000ug/mg$$

where VFw is the Volatilization Factor of water to air, assumed to be 0.5 L/m^3. A summary of screening levels developed through use of this model is provided in the Table F series of Appendix 1.

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USEPA, 1985, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources: U.S. Environmental Protection Agency, Office of Air and Radiation, Publication No. AP-42, Fourth Edition, September 1985.

USEPA, 2003, *User's Guide For Subsurface Vapor Intrusion Into Buildings*: U.S. Environmental Protection Agency Office of Emergency and Remedial Response, March 2003, www.epa.gov/oerrpage/superfund/.

USEPA, 2001, Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites: U.S. Environmental Protection Agency, Solid Waste and Emergency Response, OSWER 9355.4-24, March 2001.

USEPA, 2004, Preliminary Remediation Goals: U.S. Environmental Protection Agency, Region IX, October 2004, www.epa.gov/region09/waste/sfund/prg/intro.htm.

TABLE 1. HUMAN EXPOSURE PARAMETER DEFINITIONS AND DEFAULT VALUES

Symbol	Definition (units)	Default	References (refer to USEPA 2004 for full references)
CSFo	Cancer slope factor oral $(mg/kg-d)^{-1}$	--	Chemical specific - Appendix 1, Table J
CSFi	Cancer slope factor inhaled $(mg/kg-d)^{-1}$	--	Chemical specific - Appendix 1, Table J
RfDo	Reference dose oral (mg/kg-d)	--	Chemical specific - Appendix 1, Table J
RfDi	Reference dose inhaled (mg/kg-d)	--	Chemical specific - Appendix 1, Table J
TRr/o	Target cancer risk - residential, occupational/ industrial exposure scenario	10^{-6}	USEPA 2004
*TRctw	Target cancer risk - construction/trench worker exposure scenario	10^{-6}	model assumption
THQ	Target hazard quotient	0.2	modified from USEPA 2004
BWa	Body weight, adult (kg)	70	RAGS (Part A), USEPA 1989 (EPA/540/1-89/002) Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
BWc	Body weight, child (kg)	15	
ATc	Average time – carcinogens (days)	25,550	RAGS (Page A), USEPA 1989 (EPA/540/1-89/002)
ATn	Average time – noncarcinogens (days)	ED*365	USEPA 2004
SAar	Exposed surface area, adult res. (cm^2/day)	5,700	Dermal Assessment, USEPA 2004 (EPA/540/R-99/005)
SAaw	Exposed surface area, adult occ. (cm^2/day)	3,300	Dermal Assessment, USEPA 2004 (EPA/540/R-99/005))
SAc	Exposed surface area, child (cm^2/day)	2,800	Dermal Assessment, USEPA 2004 (EPA/540/R-99/005))
*SAac/tw	Exposed surface area, construction/trench worker (cm^2/day)	5,800	Exposure Factors, USEPA 1997 (EPA/600/P-95/002Fa)
AFar	Adherence factor, adult res. (mg/cm^2)	0.07	Dermal Assessment, USEPA 2004 (EPA/540/R-99/005)
AFaw	Adherence factor, occupational (mg/cm^2)	0.20	Dermal Assessment, USEPA 2004 (EPA/540/R-99/005)
*AFctw	Adherence factor, construction/trench worker (mg/cm^2)	0.51	Massachusetts DEP (1994)
AFc	Adherence factor, child (mg/cm^2)	0.20	Dermal Assessment, USEPA 2004 (EPA/540/R-99/005)
ABS	Skin absorption (unitless): chemical specific	--	Dermal Assessment, USEPA 2004 (EPA/540/R-99/005)
IRAa	Inhalation rate – adult (m^3/day)	20	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
IRAc	Inhalation rate – child (m^3/day)	10	Exposure Factors, USEPA 1997 (EPA/600/P-95/002Fa)
*IRActw	Inhalation rate – construction/trench worker (m^3/day)	20	Exposure Factors, USEPA 1997 (EPA/600/P-95/002Fa)
IRWa	Drinking water ingestion – adult (L/day)	2	RAGS (Part A), USEPA 1989 (EPA/540/1-89/002)
IRWc	Drinking water ingestion – child (L/day)	1	PEA Cal-EPA (DTSC, 1994)
IRSa	Soil ingestion – adult (mg/day)	100	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
IRSc	Soil ingestion – child (mg/day)	200	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
IRSo	Soil ingestion – occupational (mg/day)	50	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
*IRSctw	Soil ingestion – construction/trench worker (mg/day)	330	USEPA 2001
EFr	Exposure frequency – residential (d/y)	350	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
EFo	Exposure frequency – occupational (d/y)	250	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
*EFctw	Exposure frequency – construction/trench worker (d/y)	20	Massachusetts DEP (1994)
EDr	Exposure duration – residential (years)	30	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
EDc	Exposure duration – child (years)	6[a]	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
EDo	Exposure duration – occupational (years)	25	Exposure Factors, USEPA 1991 (OSWER No. 9285.6-03)
*EDctw	Exposure duration – construction/trench worker (years)	7	modified from Massachusetts DEP (1994)
IFSadj	Ingestion factor, soils ([mg-yr]/[kg-d])	114	RAGS (Part B, v 1991 (OSWER No. 9285.7-01B)
SFSadj	Skin contact factor, soils ([mg-yr]/[kg-d])	361	By analogy to RAGS (Part B)
InhFadj	Inhalation factor ([m^3-yr]/[kg-d])	11	By analogy to RAGS (Part B)
IFWadj	Ingestion factor, water ([1-yr]/[kg-d])	1.1	By analogy to RAGS (Part B)
VFw	Volatilization factor for water (L/m^3)	0.5	RAGS (Part B), USEPA 1991 (OSWER No. 9285.7-01B)
PEFres/oc	Particulate emission factor (m^3/kg) - residential/occupational exposure scenarios	1.32E+09	Soil Screening Guidance (USEPA 1996a)
*PEFctw	Particulate emission factor (m^3/kg) - construction/trench worker exposure scenarios	1.44E+06	Based on Construction Site Dust Emission Factors (USEPA 1974, 1985). See attached table.
VFs	Volatilization factor for soil (m3/kg)	-	Chemical specific; Soil Screening Guidance (USEPA 1996a,b)
sat	Soil saturation concentration (mg/kg)	-	Chemical specific; Soil Screening Guidance (USEPA 1996a,b)

Primary Reference: USEPA, 2004, *Preliminary Remediation Goals*: U.S. Environmental Protection Agency, Region IX, October 2004,

a Exposure duration for lifetime residents is assumed to be 30 years total. For carcinogens, exposures are combined for children (6 years) and adults (24 years).

* This document only. Not presented in USEPA Region IX PRGs.

TABLE 2. VOLATILIZATION FACTOR PARAMETER DEFINITIONS AND DEFAULT VALUES

Parameter	Definition (units)	Default
VF_s	Volatilization factor M^3/kg)	--
D_A	Apparent diffusivity (cm^2/s)	--
Q/C	Inverse of the mean conc. at the center of a 0.5-acre square source (g/m^2-s per kg/m^3)	68.81
T	Exposure interval (s)	9.5×10^8
rho_b	Dry soil bulk density (g/cm^3)	1.5
$theta_a$	Air filled soil porosity (L_{air}/L_{soil})	0.28 or n-w
n	Total soil porosity (L_{pore}/L_{soil})	0.43 or $1 - (b/s)$
$theta_w$	Water-filled soil porosity (L_{water}/L_{soil})	0.15
rho_s	Soil particle density (g/cm^3)	2.65
Di	Diffusivity in air (cm^2/s)	Chemical-specific
H	Henry's Law constant (atm-m^3/mol)	Chemical-specific
H'	Dimensionless Henry's Law constant	Calculated from H by multiplying by 41 (USEPA 1991a)
D_w	Diffusivity in water (cm^2/s)	Chemical-specific
K_d	Soil-water partition coefficient (cm3/g) = Koc x foc	Chemical-specific
K_{oc}	Soil organic carbon-water partition coefficient (cm^3/g)	Chemical-specific
f_{oc}	Fraction organic carbon in soil (g/g)	0.006 (0.6%)

TABLE 3. PARTICULATE EMISSION FACTOR PARAMETER DEFINITIONS AND DEFAULT VALUES - RESIDENTIAL/OCCUPATIONAL SCENARIOS

Parameter	Definition (units)	Default
PEF	Particulate emission factor (m^3/kg)	1.316×10^9
Q/C	Inverse of the mean concentration at the center of a 0.5-acre-square source (g/m^2-s per kg/m^3)	90.80
V	Fraction of vegetative cover (unitless)	0.5
Um	Mean annual windspeed (m/s)	4.69
Ut	Equivalent threshold value of windspeed at 7 m (m/s) 11.32	11.32
F(x)	Function dependent on Um/Ut derived using Cowherd (1985) (unitless)	0.194

TABLE 4. PARTICULATE EMISSION FACTOR FOR CONSTRUCTION/TRENCH WORKER EXPOSURE SCENARIO

Dust Generated (moderate to heavy construction) (M_{dust}):			
Dust Emission Factor (EF):	1.2	tons/mo-acre	USEPA 1974, 1985
	2400	lbs/mo-acre	conversion
	1089	kgs/mo-acre	conversion
Volume Air Passing Over Site Per Month Per Acre (V_{air}):			
Length Perpendicular To Wind (L):	1	acre	Default EF area
	43560	ft^2	conversion
	4047	m^2	conversion
	64	m	L=Area$^{0.5}$
Air Mixing Zone Height (MZ):	2	m	model assumption
Ave Wind Speed (V):	4.69	m/s	USEPA 2004 (default PRG value)
Seconds per 30.4 Day Month (S):	2.63E+06	sec/month	conversion
Volume Air (Volume-air):	1.57E+09	m^3	Volume-air=LxMZxVxS
Average Concentration Dust in Air ($C_{dust-air}$):			
Concentration Dust ($C_{dust-air}$)	6.95E-07	kg/m^3	(Cair = M_{dust}/Volume-air)
	0.695	mg/m^3	conversion
Particulate Emission Factor (PEF):			
Concentration soil in dust ($C_{dust-soil}$):	1,000,000	mg/kg	Model assumption - 100% (1000000 mg/kg) of dust is derived from on-site soil.
PEF:	1.44E+06	(mg/kg)/(mg/m^3)	PEF=$C_{dust-soil}$/$C_{dust-air}$

Attachment

Text of USEPA Region IX Preliminary Remediation Goals Document (October 2004)

APPENDIX 3

RELEVANT PORTIONS OF 2003
*USER'S GUIDE FOR EVALUATING SUBSURFACE
VAPOR INTRUSION INTO BUILDINGS*

SENSITIVITY ANALYSIS OF *JOHNSON AND
ETTINGER (1991) MODEL*

D R A F T

USER'S GUIDE FOR
EVALUATING SUBSURFACE VAPOR INTRUSION
INTO BUILDINGS

Prepared By

Environmental Quality Management, Inc.
Cedar Terrace Office Park, Suite 250
3325 Durham-Chapel Hill Boulevard
Durham, North Carolina 27707-2646

Prepared For

Industrial Economics Incorporated
2667 Massachusetts Avenue
Cambridge, Massachusetts 02140

Subcontract No. 3073-002
EPA Contract Number: 68-W-01-058
PN 030224.0001

For Submittal to

Janine Dinan, Work Assignment Manager

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF EMERGENCY AND REMEDIAL RESPONSE
ARIEL RIOS BUILDING, 5202G
1200 PENNSYLVANIA AVENUE, NW
WASHINGTON, D.C. 20460

March 14, 2003

DISCLAIMER

This document presents technical and policy recommendations based on current understanding of the phenomenon of subsurface vapor intrusion. This guidance does not impose any requirements or obligations on the U.S. Environmental Protection Agency (EPA) or on the owner/operators of sites that may be contaminated with volatile and toxic compounds. The sources of authority and requirements for addressing subsurface vapor intrusion are the applicable and relevants statutes and regulations.. This guidance addresses the assumptions and limitations that need to be considered in the evaluation of the vapor intrusion pathway. This guidance provides instructions on the use of the vapor transport model that originally was developed by P. Johnson and R. Ettinger in 1991 and subsequently modified by EPA in 1998, 2001, and again in November 2002. On November 29, 2002 EPA published Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Federal Register: November 29, 2002 Volume 67, Number 230 Page 71169-71172). This document is intended to be a companion for that guidance. Users of this guidance are reminded that the science and policies concerning vapor intrusion are complex and evolving.

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ACKNOWLEDGMENT

WHAT'S NEW IN THIS VERSION!

This revised version of the User's Guide corresponds with the release of Version 3.0 of the Johnson and Ettinger (1991) model (J&E) spreadsheets for estimating subsurface vapor intrusion into buildings. Several things have changed within the models since Version 2 was released in December 2000 and since the original version was released in September 1998. The following represent the major changes in Version 3.0 to be consistent with Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Quality from Groundwater and Soils dated November 25, 2002 as referenced below:

1. Table 1 lists the chemicals that are commonly found at contaminated sites. This list has been expanded from the list of chemicals included in Version 2 of the model. We have also applied certain criteria to determine whether it is appropriate to run the model for these contaminants. Only those contaminants for which all of the toxicological or physical chemical properties needed to make an assessment of the indoor inhalation risk are included in the spreadsheets. A chemical is considered to be sufficiently toxic if the vapor concentration of the pure component poses an incremental life time cancer risk greater than 1×10^{-6} or the noncancer hazard index is greater than 1. A chemical is considered to be sufficiently volatile if its Henry's law constant is 1×10^{-5} atm-m^3/mole or greater. The final chemical list for Version 3 includes 108 chemicals.

2. **Chemical Property Data** - The source of chemical data used in the calculation is primarily EPA's Superfund Chemical Data Matrix (SCDM) database. EPA's WATER9 database is used for chemicals not included in the SCDM database. Appendix B contains other data sources.

3. **Toxicity Values** – EPA's Integrated Risk Information System (IRIS) is the generally preferred source of carcinogenic unit risks and non-carcinogenic reference concentrations (RfCs) for inhalation exposure.[1] The following two sources were consulted, in order of preference, when IRIS values were not available: provisional toxicity values recommended by EPA's National Center for Environmental Assessment (NCEA) and EPA's Health Effects Assessment Summary Tables (HEAST). If no inhalation toxicity data could be obtained from IRIS, NCEA, or HEAST, extrapolated unit risks and/or RfCs using toxicity data for oral exposure (cancer slope factors and/or reference doses, respectively) from these same sources

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[1] U.S. EPA. 2002. Integrated Risk Information System (IRIS). http://www.epa.gov/iriswebp/iris/index.html. November.

using the same preference order were used.[2]   Note that for most compounds,
extrapolation from oral data introduces considerable uncertainty into the resulting
inhalation value. Values obtained from inhalation studies or from pharmacokinetic
modeling applied to oral doses will be less uncertain than those calculated using the
equations noted in footnote 2.

IRIS currently does not include carcinogenicity data for trichloroethylene (TCE), a
volatile contaminant frequently encountered at hazardous waste sites. The original
carcinogenicity assessment for TCE, which was based on a health risk assessment
conducted in the late 1980's, was withdrawn from IRIS in 1994. The Superfund
Technical Support Center has continued to recommend use of the cancer slope factor
from the withdrawn assessment, until a reassessment of the carcinogenicity of TCE
is completed. In 2001, the Agency published a draft of the TCE toxicity assessment
for public comment.[3] Using this guidance, TCE target concentrations for the draft
vapor intrusion guidance were calculated using a cancer slope factor identified in that
document, which is available on the NCEA web site. This slope factor was selected
because it is based on state-of-the-art methodology. However, because this document
is still undergoing review, the slope factor and the target concentrations calculated
for TCE are subject to change and should be considered "provisional" values.

Toxicity databases such as IRIS are routinely updated as new information becomes
available; the data included in the lookup tables are current as of November 2002.
Users of these models are strongly encouraged to research the latest toxicity values
for contaminants of interest from the sources noted above. In the next year, IRIS
reassessments are expected for several contaminants commonly found in subsurface
contamination whose inhalation toxicity values are currently based on extrapolation.

4.   Assumption and Limitations

The Johnson and Ettinger (J&E) Model was developed for use as a screening level
model and, consequently, is based on a number of simplifying assumptions regarding
contaminant distribution and occurrence, subsurface characteristics, transport
mechanisms, and building construction. The assumptions of the J&E Model as
implemented in EPA's spreadsheet version are listed in Section 2.11, Section 5, and

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[2] The oral-to-inhalation extrapolations assume an adult inhalation rate (IR) of 20 m^3/day and an adult body weight
(BW) of 70 kg. Unit risks (URs) were extrapolated from cancer slope factors (CSFs) using the following equation:

$$UR\ (\mu g/m^3)^{-1} = CSF\ (mg/kg/d)^{-1} * IR\ (m^3/d) * (1/BW)(kg^{-1}) * (10^{-3}\ mg/\mu g)$$

Reference concentrations (RfCs) were extrapolated from reference doses (RfDs) using the following equation:

$$RfC\ (mg/m^3) = RfD\ (mg/kg/d) * (1/IR)\ (m3/d)^{-1}\ (\ BW\ (kg)$$

[3] US EPA, Trichloroethylene Health Risk Assessment: Synthesis and Characterization – External Review Draft,
Office of Research and Development, EPA/600/P-01-002A, August, 2001.

Table 12 along with an assessment of the likelihood that the assumptions can be verified through field evaluation.

5.   Soil Parameters

A list of generally reasonable, yet conservative, model input parameters for selected soil and sampling related parameters are provided in Tables 7 and 8. These tables also provide the practical range, typical or mean value (if applicable), and most conservative value for these parameters. For building parameters with low uncertainty and sensitivity, only a single "fixed" value corresponding to the mean or typical value is provided in Table 9. Soil-dependent properties are provided in Table 10 for soils classified according to the US Soil Conservation Soil (SCS) system. If site soils are not classified according to the US SCS, Table 11 can be used to assist in selecting an appropriate SCS soil type corresponding to the available site lithologic information. Note that the selection of the soil texture class should be biased towards the coarsest soil type of significance, as determined by the site characterization program. These input parameters were developed considering soil-physics science, available studies of building characteristics, and expert opinion. Consequently, the input parameters listed in Tables 7 and 8 are considered default parameters for a first-tier assessment, which should in most cases provide a reasonably (but not overly) conservative estimate of the vapor intrusion attenuation factor for a site.

6.   Building Parameters

Building Air Exchange Rate (Default Value = 0.25 hr⁻¹)

Results from 22 studies for which building air exchange data are available were summarized in Hers et al. (2001). When all the data were analyzed, the 10th, 50th, and 90th percentile values were 0.21, 0.51, and 1.48 air exchanges per hour (AEH). Air exchange rates varied depending on season and climatic region. For example, for the winter season and coldest climatic area (Region 1, Great Lakes area and extreme northeast US), the 10th, 50th, and 90th percentile values were 0.11, 0.27, and 0.71 AEH. In contrast, for the winter season and warmest climatic area [Region 4 (southern California, Texas, Florida, Georgia)], the 10th, 50th, and 90th percentile values were 0.24, 0.48, and 1.13 AEH. For this draft guidance, a default value of 0.25 for air exchange rate was selected to represent the lower end of these distributions. The previous version of the guidance included a default value of 0.45 exchanges per hour.

Building Area and Subsurface Foundation Area (Default Value = 10 m by 10 m)

A Michigan study indicates that a 111.5 m^2 area approximately corresponds to the 10th percentile floor space area for residential single family dwellings, based on

statistics compiled by the U.S. Department of Commerce (DOC) and U.S. Housing and Urban Development (HUD). The previous median value was 9.61 m x 9.61 m.

Building Mixing Height (Default Value = 2.44 m for slab-on-grade scenario; = 3.66 m for basement scenario)

The J&E Model assumes that subsurface volatiles migrating into the building are completely mixed within the building volume, which is determined by the building area and mixing height. The building mixing height will depend on a number of factors including the building height, the heating, ventilation and air conditioning (HVAC) system operation, environmental factors such as indoor-outdoor pressure differentials and wind loading, and seasonal factors. For a single-story house, the variation in mixing height can be approximated by the room height. For a multi-story house or apartment building, the mixing height will be greatest for houses with HVAC systems that result in significant air circulation (e.g., forced-air heating systems). Mixing heights will be less for houses using electrical baseboard heaters. It is likely that mixing height is, to some degree, correlated to the building air exchange rate.

There are little data available that provide for direct inference of mixing height. There are few sites, with a small number of houses where indoor air concentrations were above background, and where both measurements at ground level and the second floor were made (CDOT, Redfields, Eau Claire). Persons familiar with the data sets for these sites indicate that in most cases a fairly significant reduction in concentrations (factor of two or greater) was observed, although at one site (Eau Claire, "S" residence), the indoor TCE concentrations were similar in both the basement and second floor of the house. For the CDOT site apartments, there was an approximate five-fold reduction between the concentrations measured for the first floor and second floor units. Less mixing would be expected for an apartment because there are less cross-floor connections than for a house. The default value chosen for a basement house scenario (3.66 m) would be representative of a two-fold reduction or attenuation in vapor concentrations between floors.

Crack Width (0.1 cm) and Crack Ratio (Default Value = 0.0002 for basement house; = 0.0038 for slab-on-grade house)

The crack width and crack ratio are related. Assuming a square house and that the only crack is a continuous edge crack between the foundation slab and wall ("perimeter crack"), the crack ratio and crack width are related as follows:

$$Crack\,Ratio = \frac{4(CrackWidth / \sqrt{Subsurface\,Foundation\,Area}}{Subsurface\,Foundation\,Area}$$

There is little information available on crack width or crack ratio. One approach used by radon researchers is to back calculate crack ratios using a model for soil gas flow through cracks and the results of measured soil gas flow rates into a building. For example, the back-calculated values for a slab/wall edge crack based on soil gas-entry rates reported in Nazaroff (1992), Revzan et al. (1991), and Nazaroff et al. (1985) range from approximately 0.0001 to 0.001. Another possible approach is to measure crack openings although this, in practice, is difficult to do. Figley and Snodgrass (1992) present data from ten houses where edge crack measurements were made. At the eight houses where cracks were observed, the cracks' widths ranged from hairline cracks up to 5 mm wide, while the total crack length per house ranged from 2.5 m to 17.3 m. Most crack widths were less than 1 mm. The suggested defaults for crack ratio is regulatory guidance, literature and models also vary. In ASTM E1739-95, a default crack ratio of 0.01 is used. The crack ratios suggested in the VOLASOIL model (developed by the Dutch Ministry of Environment) range from 0.0001 to 0.0000001. The VOLASOIL model values correspond to values for a "good" and "bad" foundation, respectively. The crack ratio used by J&E (1991) for illustrative purposes ranged from 0.001 to 0.01. The selected default values fall within the ranges observed.

Q_{soil} (Default Value = 5 L/min)

The method used to estimate the vapor flowrate into a building (Q_{soil}) is an analytical solution for two-dimensional soil gas flow to a small horizontal drain (Nazaroff 1992) ("Perimeter Crack Model"). Use of this model can be problematic in that Q_{soil} values are sensitive to soil-air permeability and consequently a wide range in flows can be predicted.

An alternate empirical approach was selected to determine the Q_{soil} value. This new approach is based on trace tests (i.e., mass balance approach). When soil gas advection is the primary mechanism for tracer intrusion into a building, the Q_{soil} value is estimated by measuring the concentrations of a chemical tracer in indoor air, outdoor air, and in soil vapor below a building, and measuring the building ventilation rate (Hers et al. 2000a; Fischer et al. 1996; Garbesi et al. 1993; Rezvan et al. 1991; Barbesi and Sectro 1989). The Q_{soil} values measured using this technique were compared to predicted rates using the Perimeter Crack model, for sites with coarse-grained soils. The Perimeter Crack model predictions are both higher and lower than the measured values, but overall are within one order of magnitude of the measured values. Although the Q_{soil} predicted by the models and measured using field tracer tests are uncertain, the results suggest that a "typical" range for houses on coarse-grained soils is on the order of 1 to 10 L/min. A disadvantage with the tracer test approach is that there are only limited data, and there do not appear to be any tracer studies for field sites with fine-grained soils.

Because the advective flow zone is relatively limited in extent, the soil type adjacent to the building foundation is of importance. In many cases, coarse-grained imported fill is placed below foundations, and either coarse-grained fill, or disturbed, loose fill is placed adjacent to the foundation walls. Therefore, a conservative approach for the purposes of this draft guidance is to assume that soil gas flow will be controlled by coarse-grained soil, and not to rely on the possible reduction in flow that would be caused by fine-grained soils near the house foundation. For these reasons, a soil gas flow rate of 5 L/min (midpoint between 1 and 10 L/min) was chosen as the input value.

7.   Convenience Changes

- Default values for soil bulk densities have been added to the lookup tables for the various soil types.
- Default values for soil water-filled porosity have been updated within the lookup tables for soil properties for the various soil types.
- The chemical data list has been expanded to include 108 chemicals. Chemical physical properties were reviewed and updated where applicable to provide the user with more accurate values.
- All of the lookup functions within the models were modified to include an exact match parameter, rather than a closest match. The models would previously return data for CAS Numbers not in the lookup tables. Although the DATENTER sheet informed the user that this CAS Number was not found, it would return values on the CHEMPROPS sheet that was the closest match. This caused some confusion and therefore was changed.
- CAS number and soil type pick lists were added to the cells within the models where the user is required to provide data in a specific format. The pick lists were added to assist the user from entering data that are not an acceptable parameter.
- All models were modified to require the user to specify the soil type of each stratum. In addition, a button was added that allows the user to automatically retrieve the default values for the soil type selected. These additions were added as a convenience to the user and soil selection can be ignored should site-specific data be available.
- All models were modified to include an input for the average vapor flow rate into the building (Q_{soil}) in liters/minute (L/min). This value can be left blank and the model will calculate the value of Q_{soil} as was done in previous versions.
- All models were also modified to include a button that will reset the default value on the DATENTER sheet. This button will allow the user to clear all values and reset the default values or reset only those values that have a default value. The user is also allowed to specify whether the values should be reset for the basement or slab-on-grade scenario.

SECTION 1

INTRODUCTION TO THE VAPOR INTRUSION MODEL
THEORY AND APPLICATION

Volatilization of contaminants located in subsurface soils or in groundwater, and the subsequent mass transport of these vapors into indoor spaces constitutes a potential inhalation exposure pathway, which may need to be evaluated when preparing risk assessments. Likewise, this potential indoor inhalation exposure pathway may need evaluation when estimating a risk-based soil or groundwater concentration below which associated adverse health effects are unlikely.

Johnson and Ettinger (J&E) (1991) introduced a screening-level model that incorporates both convective and diffusive mechanisms for estimating the transport of contaminant vapors emanating from either subsurface soils or groundwater into indoor spaces located directly above the source of contamination. In their article, J&E reported that the results of the model were in qualitative agreement with published experimental case histories and in good qualitative and quantitative agreement with detailed three-dimensional numerical modeling of radon transport into houses.

The J&E Model is a one-dimensional analytical solution to convective and diffusive vapor transport into indoor spaces and provides an estimated attenuation coefficient that relates the vapor concentration in the indoor space to the vapor concentration at the source of contamination. The model is constructed as both a steady-state solution to vapor transport (infinite or non-diminishing source) and as a quasi-steady-state solution (finite or diminishing source). Inputs to the model include chemical properties of the contaminant, saturated and unsaturated zone soil properties, and structural properties of the building.

This manual provides documentation and instructions for using the vapor intrusion model as provided in the accompanying spreadsheets.

Model results (both screening and advanced) are provided as either a risk-based soil or groundwater concentration, or as an estimate of the actual incremental risks associated with a user-defined initial concentration. That is to say that the model will reverse-calculate an "acceptable" soil or groundwater concentration given a user-defined risk level (i.e., target risk level or target hazard quotient), or the model may be used to forward-calculate an incremental cancer risk or hazard quotient based on an initial soil or groundwater concentration.

The infinite source models for soil contamination and groundwater contamination should be used as first-tier screening tools. In these models, all but the most sensitive model parameters have

been set equal to central tendency or upper bound values. Values for the most sensitive parameters may be user-defined.

More rigorous estimates may be obtained using site-specific data and the finite source model for soil contamination. Because the source of groundwater contamination may be located upgradient of the enclosed structure for which the indoor inhalation pathway is to be assessed, the advanced model for contaminated groundwater is based on an infinite source of contamination, however, site-specific values for all other model parameters may be user-defined.

In addition to the finite and infinite source models referred to above, two models that allow the user to input empirical soil gas concentration and sampling depth information directly into the spreadsheets. These models will subsequently estimate the resulting steady-state indoor air concentrations and associated health risks.

Because of the paucity of empirical data available for either bench-scale or field-scale verification of the accuracy of these models, as well as for other vapor intrusion models, the user is advised to consider the variation in input parameters and to explore and quantify the impacts of assumptions on the uncertainty of model results. At a minimum, a range of results should be generated based on variation of the most sensitive model parameters.

SECTION 2

MODEL THEORY

Chemical fate and transport within soils and between the soil column and enclosed spaces are determined by a number of physical and chemical processes. This section presents the theoretical framework on which the J&E Model is based, taking into account the most significant of these processes. In addition, this section also presents the theoretical basis for estimating values for some of the most sensitive model parameters when empirical field data are lacking. The fundamental theoretical development of this model was performed by J&E (1991).

2.1   MODEL SETTING

Consider a contaminant vapor source (C_{source}) located some distance (L_T) below the floor of an enclosed building constructed with a basement or constructed slab-on-grade. The source of contamination is either a soil-incorporated volatile contaminant or a volatile contaminant in solution with groundwater below the top of the water table.

Figure 1 is a simplified conceptual diagram of the scenario where the source of contamination is incorporated in soil and buried some distance below the enclosed space floor. At the top boundary of contamination, molecular diffusion moves the volatilized contaminant toward the soil surface until it reaches the zone of influence of the building. Here convective air movement within the soil column transports the vapors through cracks between the foundation and the basement slab floor. This convective sweep effect is induced by a negative pressure within the structure caused by a combination of wind effects and stack effects due to building heating and mechanical ventilation.

Figure 2 illustrates the scenario where the source of contamination is below the top of the water table. Here the contaminant must diffuse through a capillary zone immediately above the water table and through the subsequent unsaturated or vadose zone before convection transports the vapors into the structure.

The suggested minimum site characterization information for a first-tier evaluation of the vapor intrusion pathway includes: site conceptual model, nature and extent of contamination distribution, soil lithologic descriptions, groundwater concentrations, and/or possibly near source soil vapor concentrations. The number of samples and measurements needed to establish this information varies by site, and it is not possible to provide a hard and fast rule.

3
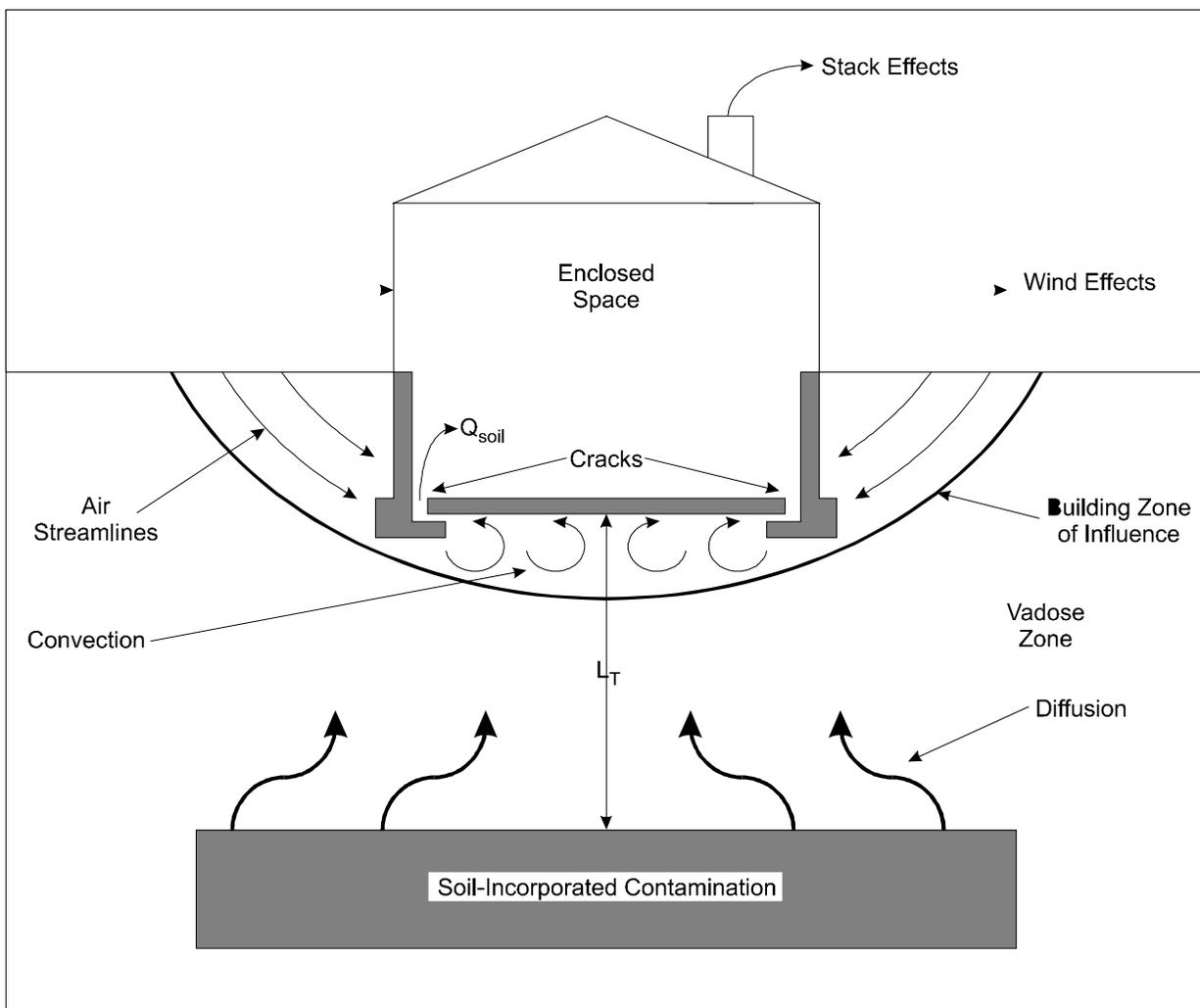
Figure 1. Pathway for Subsurface Vapor Intrusion into Indoor Air
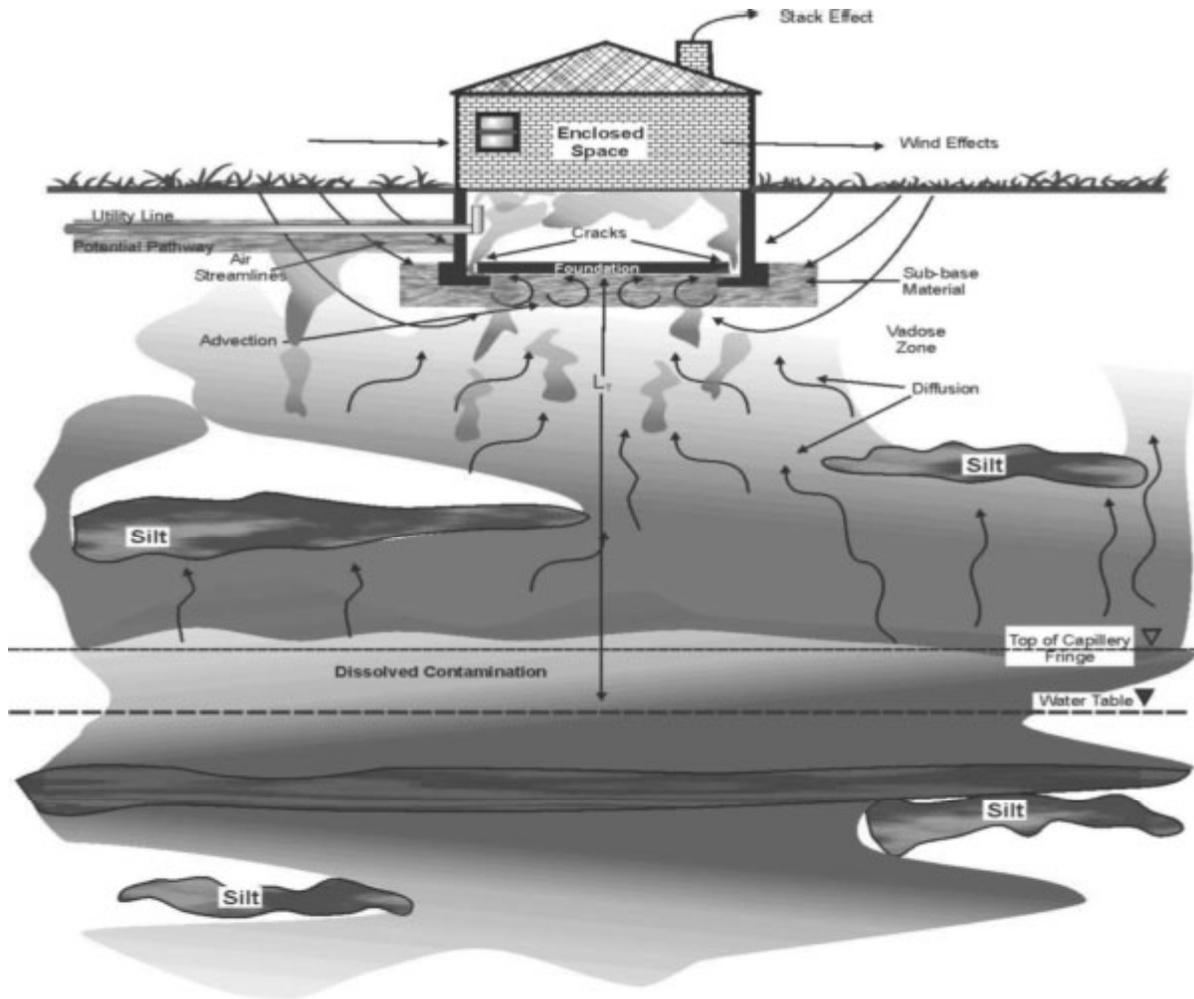
Figure 2. Vapor Pathway into Buildings

Based on the conceptual site model, the user can select the appropriate spreadsheet corresponding to the vapor source at the site and determine whether to use the screening level spreadsheet (which accommodates only one soil type above the capillary fringe) or the more advanced version (which allows up to three layers above the capillary fringe). As most of the inputs to the J&E Model are not collected during a typical site characterization, conservative inputs are typically estimated or inferred from available data and other non-site specific sources of information.

Table 1 lists 114 chemicals that may be found at hazardous waste sites and it indicates whether the chemical is sufficiently toxic and volatile to result in a potentially unacceptable indoor inhalation risk. It also provides a column for checking off the chemicals found or reasonably suspected to be present in the subsurface at a site. Under this approach, a chemical is considered sufficiently toxic if the vapor concentration of the pure component poses an incremental lifetime cancer risk greater than 10^{-6} or results in a non-cancer hazard index greater than one. A chemical is considered sufficiently volatile if its Henry's Law Constant is 1×10^{-5} atm-m^3/mol or greater (EPA, 1991). It is assumed that if a chemical does not meet both of these criteria, it need not be further considered as part of the evaluation. Table 1 also identifies six chemicals that meet the toxicity and volatility criteria but are not included in the vapor intrusion models because one or more of the needed physical or chemical properties has not been found in the literature.

The rate of soil gas entry (Q_{soil}) or average vapor flow rate into the building is a function solely of convection; however, the vapor concentration entering the structure may be limited by either convection or diffusion depending upon the magnitude of the source-building separation (L_T).

2.2   VAPOR CONCENTRATION AT THE SOURCE OF CONTAMAINATION

With a general concept of the problem under consideration, the solution begins with an estimate of the vapor concentration at the source of contamination.

In the case of soil contamination, the initial concentration (C_R) does not contain a residual-phase (e.g., nonaqueous-phase liquid or solid); and in the case of contaminated groundwater, the initial contaminant concentration (C_W) is less than the aqueous solubility limit (i.e., in solution with water).

Given these initial conditions, C_{source} for soil contamination may be estimated from Johnson et al. (1990) as:

$$ C_{source} = \frac{H'_{TS} \, C_R \, \rho_b}{\theta_w + K_d \rho_b + H'_{TS} \, \theta_a} \tag{1} $$

where C_{source} = Vapor concentration at the source of contamination, g/cm^3-v

                    H'$_{TS}$ = Henry's law constant at the system (soil) temperature, dimensionless

TABLE 1. SCREENING LIST OF CHEMICALS

CAS No.	Chemical	Is Chemical Sufficiently Toxic?[1]	Is Chemical Sufficiently Volatile?[2]	Check Here if Known or Reasonably Suspected to be Present [3]
83329	Acenaphthene	YES	YES	
75070	Acetaldehyde	YES	YES	
67641	Acetone	YES	YES	
75058	Acetronitrile	YES	YES	
98862	Acetophenone	YES	YES	
107028	Acrolein	YES	YES	
107131	Acrylonitrile	YES	YES	
309002	Aldrin	YES	YES	
319846	Alpha-HCH (alpha-BHC)	YES	YES	
62533	Aniline	YES	NO	NA
120127	Anthracene	NO	YES	NA
56553	Benz(a)anthracene	YES	NO	NA
100527	Benzaldehyde	YES	YES	
71432	Benzene	YES	YES	
50328	Benzo(a)pyrene	YES	NO	NA
205992	Benzo(b)fluoranthene	YES	YES	
207089	Benzo(k)fluoranthene	NO	NO	NA
65850	Benzoic Acid	NO	NO	NA
100516	Benzyl alcohol	YES	NO	NA
100447	Benzylchloride	YES	YES	
91587	Beta-Chloronaphthalene [3]	YES	YES	
319857	Beta-HCH(beta-BHC)	YES	NO	NA
92524	Biphenyl	YES	YES	
111444	Bis(2-chloroethyl)ether	YES	YES	
108601	Bis(2-chloroisopropyl)ether [3]	YES	YES	
117817	Bis(2-ethylhexyl)phthalate	NO	NO	NA
542881	Bis(chloromethyl)ether [3]	YES	YES	
75274	Bromodichloromethane	YES	YES	
75252	Bromoform	YES	YES	
106990	1,3-Butadiene	YES	YES	
71363	Butanol	YES	NO	NA
85687	Butyl benzyl phthalate	NO	NO	NA
86748	Carbazole	YES	NO	NA
75150	Carbon disulfide	YES	YES	
56235	Carbon tetrachloride	YES	YES	
57749	Chlordane	YES	YES	

(continued)

CAS No.	Chemical	Is Chemical Sufficiently Toxic?[1]	Is Chemical Sufficiently Volatile?[2]	Check Here if Known or Reasonably Suspected to be Present [3]
126998	2-Chloro-1,3-butadiene(chloroprene)	YES	YES	
108907	Chlorobenzend	YES	YES	
109693	1-Chlorobutane	YES	YES	
124481	Chlorodibromomethane	YES	YES	
75456	Chlorodifluoromethane	YES	YES	
75003	Chloroethane (ethyl chloride)	YES	YES	
67663	Chloroform	YES	YES	
95578	2-Chlorophenol	YES	YES	
75296	2-Chloropropane	YES	YES	
218019	Chrysene	YES	YES	
156592	Cis-1,2-Dichloroethylene	YES	YES	
123739	Crotonaldehyde(2-butenal)	YES	YES	
998828	Cumene	YES	YES	
72548	DDD	YES	NO	NA
72559	DDE	YES	YES	
50293	DDT	YES	NO	NA
53703	Dibenz(a,h)anthracene	YES	NO	NA
132649	Dibenzofuran	YES	YES	
96128	1,2-Dibromo-3-chloropropane [3]	YES	YES	
106934	1,2-Dibromoethane(ethylene dibromide)	YES	YES	
541731	1,3-Dichlorobenzene	YES	YES	
95501	1,2-Dichlorobenzene	YES	YES	
106467	1,4-Dichlorobenzene	YES	YES	
91941	3,3-Dichlorobenzidine	YES	NO	NA
75718	Dichlorodifluoromethane	YES	YES	
75343	1,1-Dichloroethane	YES	YES	
107062	1,2-dichloroethane	YES	YES	
75354	1,1-Dichloroethylene	YES	YES	
120832	2,4-Dichloroephenol	YES	NO	NA
78875	1,2-Dichloropropane	YES	YES	
542756	1,3-Dichloropropene	YES	YES	
60571	Dieldrin	YES	YES	
84662	Diethylphthalate	YES	NO	NA
105679	2,4-Dimethylphenol	YES	NO	NA
131113	Dimethylphthalate	NA	NO	NA
84742	Di-n-butyl phthalate	NO	NO	NA

(continued)

CAS No.	Chemical	Is Chemical Sufficiently Toxic?[1]	Is Chemical Sufficiently Volatile?[2]	Check Here if Known or Reasonably Suspected to be Present [3]
534521	4,6 Dinitro-2methylphenol (4, 6-dinitro-o-cresol)	YES	NO	NA
51285	2,4-Dinitrophenol	YES	NO	NA
121142	2,4-Dinitrotoluene	YES	NO	NA
606202	2,6-Dinitrotoluene	YES	NO	NA
117840	Di-n-octyl phthalate	NO	YES	NA
115297	Endosulfan	YES	YES	
72208	Endrin	YES	NO	NA
106898	Epichlorohydrin [3]	YES	YES	
60297	Ethyl ether	YES	YES	
141786	Ethylacetate	YES	YES	
100414	Ethylbenzene	YES	YES	
75218	Ethylene oxide	YES	YES	
97632	Ethylmethacrylate	YES	YES	
206440	Fluoranthene	NO	YES	NA
86737	Fluorene	YES	YES	
110009	Furane	YES	YES	
58899	Gamma-HCH(Lindane)	YES	YES	
76448	Heptachlor	YES	YES	
1024573	Heptachlor epoxide	YES	NO	NA
87683	Hexachloro-1,3-butadiene	YES	YES	
118741	Hexachlorobenzene	YES	YES	
77474	Hexachlorocyclopentadiene	YES	YES	
67721	Hexachloroethane	YES	YES	
110543	Hexane	YES	YES	
74908	Hydrogene cyanide	YES	YES	
193395	Indeno (1,2,3-cd)pyrene	NO	NO	NA
78831	Isobutanol	YES	YES	
78591	Isophorone	YES	NO	NA
7439976	Mercury (elemental)	YES	YES	
126987	Methacrylonitrile	YES	YES	
72435	Methoxychlor	YES	YES	
79209	Methy acetate	YES	YES	
96333	Methyl acrylate	YES	YES	
74839	Methyl bromide	YES	YES	
74873	Methyl chloride (chloromethane)	YES	YES	
108872	Methylcyclohexane	YES	YES	

(continued)

CAS No.	Chemical	Is Chemical Sufficiently Toxic?[1]	Is Chemical Sufficiently Volatile?[2]	Check Here if Known or Reasonably Suspected to be Present [3]
74953	Methylene bromide	YES	YES	
75092	Methylene chloride	YES	YES	
78933	Methylethylketone (2-butanone)	YES	YES	
108101	Methylisobutylketone (4-methyl-2-pentanone)	YES	YES	
80626	Methylmethacrylate	YES	YES	
91576	2-Methylnaphthalene	YES	YES	
108394	3-Methylphenol(m-cresol)	YES	NO	NA
95487	2-Methylphenol(o-cresol)	YES	NO	NA
106455	4-Methylphenol (p-cresol)	YES	NO	NA
99081	m-Nitrotoluene	YES	NO	NA
1634044	MTBE	YES	YES	
108383	m-Xylene	YES	YES	
91203	Naphthalene	YES	YES	
104518	n-Butylbenzene	YES	YES	
98953	Nitrobenzene	YES	YES	
100027	4-Nitrophenol	YES	NO	NA
79469	2-Nitropropane	YES	YES	
924163	N-nitroso-di-n-butylamine [3]	YES	YES	
621647	N-Nitroso-di-n-propylamine	YES	NO	NA
86306	N-Nitrosodiphenylamine	YES	NO	NA
103651	n-Propylbenzene	YES	YES	
88722	o-Nitrotoluene	YES	YES	
95476	o-Xylene	YES	YES	
106478	p-Chloroaniline	YES	NO	NA
87865	Pentachlorophenol	YES	NO	NA
108952	Phenol	YES	NO	NA
99990	p-Nitrotoluene	YES	NO	NA
106423	p-Xylene	YES	YES	
129000	Pyrene	YES	YES	
110861	Pyridine	YES	NO	NA
135988	Sec-Butylbenzene	YES	YES	
100425	Styrene	YES	YES	
98066	Tert-Butylbenzene	YES	YES	
630206	1,1,1,2-Tetrachloroethane	YES	YES	
79345	1,1,2,2,-Tetrachloroethane	YES	YES	
127184	Tetrachloroethylene	YES	YES	

(continued)

CAS No.	Chemical	Is Chemical Sufficiently Toxic?[1]	Is Chemical Sufficiently Volatile?[2]	Check Here if Known or Reasonably Suspected to be Present [3]
108883	Toluene	YES	YES	
8001352	Toxaphen	YES	NO	NA
156605	Trans-1,2-Dichloroethylene	YES	YES	
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	YES	YES	
120821	1,2,4-Trichlorobenzene	YES	YES	
79005	1,1,2-Trichloroethane	YES	YES	
71556	1,1,1-Trichloroethane	YES	YES	
79016	Trichloroethylene	YES	YES	
75694	Trichlorofluoromethane	YES	YES	
95954	2,4,5-Trichlorophenol	YES	NO	NA
88062	2,4,6-Trichlorophenol	YES	NO	NA
96184	1,2,3-Trichloropropane	YES	YES	
95636	1,2,4-Trimethylbenzene	YES	YES	
108678	1,3,5-Trimethylbenzene	YES	YES	
108054	Vinyl acetate	YES	YES	
75014	Vinyl chloride (chloroethene)	YES	YES	

[1] A chemical is considered sufficiently toxic if the vapor concentration of the pure component poses an incremental lifetime cancer risk greater than 10^{-6} or a non-cancer hazard index greater than 1.

[2] A chemical is considered sufficiently volatile if its Henry's law constant is 1×10^{-5} atm-m^3/mol or greater.

[3] One or more of the physical chemical properties required to run the indoor air vapor intrusion models was not found during a literature search conducted March 2003.

C_R = Initial soil concentration, g/g

ρ_b = Soil dry bulk density, g/cm^3

θ_w = Soil water-filled porosity, cm^3/cm^3

K_d = Soil-water partition coefficient, cm^3/g (= K_{oc} x f_{oc})

θ_a = Soil air-filled porosity, cm^3/cm^3

K_{oc} = Soil organic carbon partition coefficient, cm^3/g

f_{oc} = Soil organic carbon weight fraction.

If the initial soil concentration includes a residual phase, the user is referred to the NAPL-SCREEN or NAPL-ADV models as discussed in Appendix A. These models estimate indoor air concentrations and associated risks for up to 10 user-defined contaminants that comprise a residual phase mixture in soils.

C_{source} for groundwater contamination is estimated assuming that the vapor and aqueous-phases are in local equilibrium according to Henry's law such that:

$$C_{source} = H'_{TS} C_w \tag{2}$$

where C_{source} = Vapor concentration at the source of contamination, g/cm^3-v

H'_{TS} = Henry's law constant at the system (groundwater) temperature, dimensionless

C_w = Groundwater concentration, g/cm^3-w.

The dimensionless form of the Henry's law constant at the system temperature (i.e., at the average soil/groundwater temperature) may be estimated using the Clapeyron equation by:

$$H'_{TS} = \frac{\exp\left[-\dfrac{\Delta H_{v,TS}}{R_c}\left(\dfrac{1}{T_S} - \dfrac{1}{T_R}\right)\right] H_R}{RT_S} \tag{3}$$

where H'_{TS} = Henry's law constant at the system temperature, dimensionless

$\Delta H_{v,TS}$ = Enthalpy of vaporization at the system temperature, cal/mol

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T_S = System temperature, °K

T_R = Henry's law constant reference temperature, °K

H_R = Henry's law constant at the reference temperature, atm-m^3/mol

R_C = Gas constant (= 1.9872 cal/mol - °K)

R   = Gas constant (= 8.205 E-05 atm-m^3/mol-°K).

The enthalpy of vaporization at the system temperature can be calculated from Lyman et al. (1990) as:

$$\Delta H_{v,TS} = \Delta H_{v,b} \left[\frac{(1 - T_S / T_C)}{(1 - T_B / T_C)} \right]^n \qquad (4)$$

where $\Delta H_{v,TS}$ = Enthalpy of vaporization at the system temperature, cal/mol

$\Delta H_{v,b}$ = Enthalpy of vaporization at the normal boiling point, cal/mol

T_S = System temperature, °K

T_C = Critical temperature, °K

T_B = Normal boiling point, °K

n   = Constant, unitless.

Table 2 gives the value of n as a function of the ratio T_B/T_C.

TABLE 2. VALUES OF EXPONENT n AS A FUNCTION OF T_B/T_C

T_B/T_C	N
< 0.57	0.30
0.57 - 0.71	0.74 (T_B/T_C) - 0.116
> 0.71	0.41

2.3   DIFFUSION THROUGH THE CAPILLARY ZONE

Directly above the water table, a saturated capillary zone exists whereby groundwater is held within the soil pores at less than atmospheric pressure (Freeze and Cherry, 1979). Between drainage and wetting conditions, the saturated water content varies but is always less than the fully saturated water content which is equal to the soil total porosity. This is the result of air entrapment in the pores during the wetting process (Gillham, 1984). Upon rewetting, the air content of the capillary zone will be higher than after main drainage. Therefore, the air content will vary as a function of groundwater recharge and discharge. At the saturated water content, Freijer (1994) found that the relative vapor-phase diffusion coefficient was almost zero. This implies that all remaining air-filled soil pores are disconnected and thus blocked for gas diffusion. As the air-filled porosity increased, however, the relative diffusion coefficient indicated the presence of connected air-filled pores that corresponded to the air-entry pressure head. The air-entry pressure head corresponds with the top of the saturated capillary zone. Therefore, to allow for the calculation of the effective diffusion coefficient by lumping the gas-phase and aqueous-phase together, the water-filled soil porosity in the capillary zone ($\theta_{w,cz}$) is calculated at the air-entry pressure head (h) according to the procedures of Waitz et al. (1996) and the van Genuchten equation (van Genuchten, 1980) for the water retention curve:

$$\theta_{w,cz} = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + (\alpha_1 h)^N\right]^M} \tag{5}$$

where $\theta_{w,cz}$ = Water-filled porosity in the capillary zone, cm^3/cm^3

θ_r = Residual soil water content, cm^3/cm^3

θ_s = Saturated soil water content, cm^3/cm^3

α_1 = Point of inflection in the water retention curve where $d\,\theta_w/dh$ is
                  maximal, cm^{-1}

h   = Air-entry pressure head, cm (= $1/\alpha_1$ and assumed to be positive)

N   = van Genuchten curve shape parameter, dimensionless

M   = 1 - (1/N).

With a calculated value of $\theta_{w,cz}$ within the capillary zone at the air-entry pressure head, the air-filled porosity within the capillary zone ($\theta_{a,cz}$) corresponding to the minimum value at which gas diffusion is relevant is calculated as the total porosity (n) minus $\theta_{w,cz}$.

Hers (2002) computed the SCS class average values of the water filled porosity and the height of the capillary zone SCS soil textural classifications. Table 3 provides the class average values for each of the SCS soil types. These data replace the mean values developed by Schaap and

Leij (1998) included in the previous U.S. Environmental Protection Agency (EPA) version of the J&E Models. With the class average values presented in Table 3, a general estimate can be made of the values of $\theta_{w,cz}$ and $\theta_{a,cz}$ for each soil textural classification.

The total concentration effective diffusion coefficient across the capillary zone (D_{cz}^{eff}) may then be calculated using the Millington and Quirk (1961) model as:

$$D_{cz}^{eff} = D_a\left(\theta_{a,cz}^{3.33}/n_{cz}^2\right) + \left(D_w/H_{TS}'\right)\left(\theta_{w,cz}^{3.33}/n_{cz}^2\right) \tag{6}$$

where

D_{cz}^{eff} = Effective diffusion coefficient across the capillary zone, cm^2/s

D_a = Diffusivity in air, cm^2/s

$\theta_{a,cz}$ = Soil air-filled porosity in the capillary zone, cm^3/cm^3

n_{cz} = Soil total porosity in the capillary zone, cm^3/cm^3

D_w = Diffusivity in water, cm^2/s

H'_{TS} = Henry's law constant at the system temperature, dimensionless

$\theta_{w,cz}$ = Soil water-filled porosity in the capillary zone, cm^3/cm^3.

According to Fick's law of diffusion, the rate of mass transfer across the capillary zone can be approximated by the expression:

$$E = A\left(C_{source} - C_{g0}\right)D_{cz}^{eff}/L_{cz} \tag{7}$$

where

E = Rate of mass transfer, g/s

A = Cross-sectional area through which vapors pass, cm^2

C_{source} = Vapor concentration within the capillary zone, g/cm^3-v

C_{g0} = A known vapor concentration at the top of the capillary zone, g/cm^3-v (C_{g0} is assumed to be zero as diffusion proceeds upward)

D_{cz}^{eff} = Effective diffusion coefficient across the capillary zone, cm^2/s

L_{cz} = Thickness of capillary zone, cm.

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TABLE 3. CLASS AVERAGE VALUES OF THE VAN GENUCHTEN SOIL WATER
RETENTION PARAMETERS FOR THE 12 SCS SOIL TEXTURAL CLASSIFICATIONS

Soil texture (USDA)	Saturated water content, θ_s	Residual water Content, θ_r	van Genuchten parameters		
			α_1 (1/cm)	N	M
Clay	0.459	0.098	0.01496	1.253	0.2019
Clay loam	0.442	0.079	0.01581	1.416	0.2938
Loam	0.399	0.061	0.01112	1.472	0.3207
Loamy sand	0.390	0.049	0.03475	1.746	0.4273
Silt	0.489	0.050	0.00658	1.679	0.4044
Silty loam	0.439	0.065	0.00506	1.663	0.3987
Silty clay	0.481	0.111	0.01622	1.321	0.2430
Silty clay loam	0.482	0.090	0.00839	1.521	0.3425
Sand	0.375	0.053	0.03524	3.177	0.6852
Sandy clay	0.385	0.117	0.03342	1.208	0.1722
Sandy clay loam	0.384	0.063	0.02109	1.330	0.2481
Sandy loam	0.387	0.039	0.02667	1.449	0.3099

The value of C_{source} is calculated using Equation 2; the value of A is assumed to be 1 cm^2; and the value of D_{cz}^{eff} is calculated by Equation 6. What remains is a way to estimate a value for L_{cz}.

Lohman (1972) and Fetter (1994) estimated the rise of the capillary zone above the water table using the phenomenon of capillary such that water molecules are subject to an upward attractive force due to surface tension at the air-water interface and the molecular attraction of the liquid and solid phases. The rise of the capillary zone can thus be estimated using the equation for the height of capillary rise in a bundle of tubes of various diameters equivalent to the diameters between varying soil grain sizes. Fetter (1994) estimated the mean rise of the capillary zone as:

$$L_{cz} = \frac{2\ \alpha_2\ COS\ \lambda}{\rho_w\ g\ R} \tag{8}$$

where

L_{cz} = Mean rise of the capillary zone, cm

α_2 = Surface tension of water, g/s (= 73)

λ = Angle of the water meniscus with the capillary tube, degrees (assumed to be zero)

ρ_w = Density of water, g/cm^3 (= 0.999)

g = Acceleration due to gravity, cm/s^2 (= 980)

R = Mean interparticle pore radius, cm

and;

$$R = 0.2D \tag{9}$$

where

R = Mean interparticle pore radius, cm

D = Mean particle diameter, cm.

Assuming that the default values of the parameters given in Equation 8 are for groundwater between 5° and 25°C, Equation 8 reduces to:

$$L_{cz} = \frac{0.15}{R}\ . \tag{10}$$

Nielson and Rogers (1990) estimated the arithmetic mean particle diameter for each of the 12 SCS soil textural classifications at the mathematical centroid calculated from its classification area (Figure 3). Table 4 shows the centroid compositions and mean particle sizes of the 12 SCS soil textural   classes.

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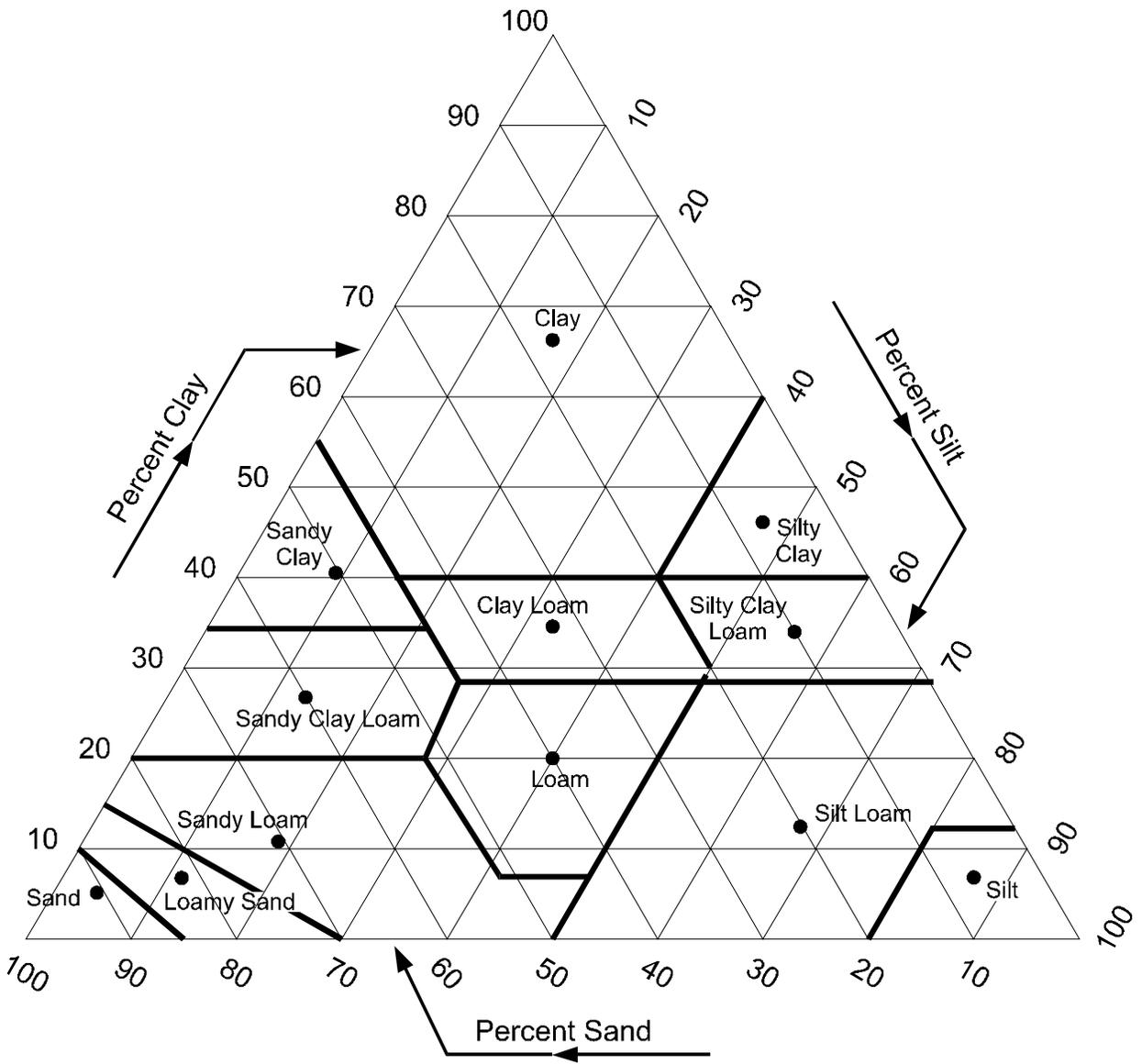
Figure 3. U.S. Soil Conservation Service Classification Chart Showing Centroid Compositions (Solid Circles)

TABLE 4. CENTROID COMPOSITIONS, MEAN PARTICLE DIAMETERS AND DRY BULK DENSITY OF THE 12 SCS SOIL TEXTURAL CLASSIFICATIONS

Textural class	% clay	% silt	% sand	Arithmetic mean particle diameter, cm	Dry Bulk Density g/cm^3
Sand	3.33	5.00	91.67	0.044	1.66
Loamy sand	6.25	11.25	82.50	0.040	1.62
Sandy loam	10.81	27.22	61.97	0.030	1.62
Sandy clay loam	26.73	12.56	60.71	0.029	1.63
Sandy clay	41.67	6.67	51.66	0.025	1.63
Loam	18.83	41.01	40.16	0.020	1.59
Clay loam	33.50	34.00	32.50	0.016	1.48
Silt loam	12.57	65.69	21.74	0.011	1.49
Clay	64.83	16.55	18.62	0.0092	1.43
Silty clay loam	33.50	56.50	10.00	0.0056	1.63
Silt	6.00	87.00	7.00	0.0046	1.35
Silty clay	46.67	46.67	6.66	0.0039	1.38

Given the mean particle diameter data in Table 4, the mean thickness of the capillary zone may then be estimated using Equations 9 and 10.

2.4   DIFFUSION THROUGH THE UNSATURATED ZONE

The effective diffusion coefficient within the unsaturated zone may also be estimated using the same form as Equation 6:

$$D_i^{eff} = D_a\left(\theta_{a,i}^{3.33}/n_i^2\right) + \left(D_w/H_{TS}'\right)\left(\theta_{w,i}^{3.33}/n_i^2\right) \tag{11}$$

where $\qquad$ D_i^{eff} $\qquad$ = Effective diffusion coefficient across soil layer i, cm^2/s

D_a $\qquad$ = Diffusivity in air, cm^2/s

$\theta_{a,i}$ $\qquad$ = Soil air-filled porosity of layer i, cm^3/cm^3

n_i $\qquad$ = Soil total porosity of layer i, cm^3/cm^3

D_w $\qquad$ = Diffusivity in water, cm^2/s

$\theta_{w,i}$ $\qquad$ = Soil water-filled porosity of layer i, cm^3/cm^3

H'_{TS} $\qquad$ = Henry's law constant at the system temperature, dimensionless

The overall effective diffusion coefficient for systems composed of n distinct soil layers between the source of contamination and the enclosed space floor is:

$$D_T^{eff} = \frac{L_T}{\sum_{i=0}^{n} L_i / D_i^{eff}} \qquad (12)$$

where $\qquad$ D_T^{eff} $\qquad$ = Total overall effective diffusion coefficient, cm^2/s

L_i $\qquad$ = Thickness of soil layer i, cm

D_i^{eff} $\qquad$ = Effective diffusion coefficient across soil layer i, cm^2/s

L_T $\qquad$ = Distance between the source of contamination and the bottom of the enclosed space floor, cm.

Note that in the case of cracks in the floor of the enclosed space, the value of L_T does not include the thickness of the floor, nor does the denominator of Equation 12 include the thickness of the floor and the associated effective diffusion coefficient across the crack(s). An unlimited number of soil layers, including the capillary zone, may be included in Equation 12, but all layers must be located between the source of contamination and the enclosed space floor.

2.5 THE INFINITE SOURCE SOLUTION TO CONVECTIVE AND DIFFUSIVE TRANSPORT

Under the assumption that mass transfer is steady-state, J&E (1991) give the solution for the attenuation coefficient (α) as:

$$\alpha = \frac{\left[\left(\dfrac{D_T^{eff}\, A_B}{Q_{building}\, L_T}\right) x\, \exp\left(\dfrac{Q_{soil}\, L_{crack}}{D^{crack}\, A_{crack}}\right)\right]}{\left[\exp\left(\dfrac{Q_{soil}\, L_{crack}}{D_{crack}\, A_{crack}}\right) + \left(\dfrac{D_T^{eff}\, A_B}{Q_{building}\, L_T}\right) + \left(\dfrac{D_T^{eff}\, A_B}{Q_{soil}\, L_T}\right)\left[\exp\left(\dfrac{Q_{soil}\, L_{crack}}{D^{crack}\, A_{crack}}\right) - 1\right]\right]} \tag{13}$$

where α = Steady-state attenuation coefficient, unitless

       D_T^{eff} = Total overall effective diffusion coefficient, cm^2/s

       A_B = Area of the enclosed space below grade, cm^2

       $Q_{building}$ = Building ventilation rate, cm^3/s

       L_T = Source-building separation, cm

       Q_{soil} = Volumetric flow rate of soil gas into the enclosed space, cm^3/s

       L_{crack} = Enclosed space foundation or slab thickness, cm

       A_{crack} = Area of total cracks, cm^2

       D_{crack} = Effective diffusion coefficient through the cracks, cm^2/s (assumed equivalent to D_i^{eff} of soil layer i in contact with the floor).

       The total overall effective diffusion coefficient is calculated by Equation 12. The value of A_B includes the area of the floor in contact with the underlying soil and the total wall area below grade. The building ventilation rate ($Q_{building}$) may be calculated as:

$$Q_{building} = (L_B\, W_B\, H_B\, ER) / 3{,}600\ s/h \tag{14}$$

where $Q_{building}$ = Building ventilation rate, cm^3/s

       L_B = Length of building, cm

       W_B = Width of building, cm

       H_B = Height of building, cm

ER = Air exchange rate, (1/h).

The building dimensions in Equation 14 are those dimensions representing the total "living" space of the building; this assumes that the total air volume within the structure is well mixed and that any vapor contaminant entering the structure is instantaneously and homogeneously distributed.

The volumetric flow rate of soil gas entering the building (Q_{soil}) is calculated by the analytical solution of Nazaroff (1988) such that:

$$Q_{soil} = \frac{2\,\pi\Delta P\,k_v\,X_{crack}}{\mu\,\ln\left(2\,Z_{crack}\,/\,r_{crack}\right)}$$
(15)

where Q_{soil} = Volumetric flow rate of soil gas entering the building, cm^3/s

π = 3.14159

ΔP = Pressure differential between the soil surface and the enclosed space, $g/cm\text{-}s^2$

k_v = Soil vapor permeability, cm^2

X_{crack} = Floor-wall seam perimeter, cm

μ = Viscosity of air, g/cm-s

Z_{crack} = Crack depth below grade, cm

r_{crack} = Equivalent crack radius, cm.

Equation 15 is an analytical solution to vapor transport solely by pressure-driven air flow to an idealized cylinder buried some distance (Z_{crack}) below grade; the length of the cylinder is taken to be equal to the building floor-wall seam perimeter (X_{crack}). The cylinder, therefore, represents that portion of the building below grade through which vapors pass. The equivalent radius of the floor-wall seam crack (r_{crack}) is given in J&E (1991) as:

$$r_{crack} = \eta\left(A_B\,/\,X_{crack}\right)$$
(16)

where r_{crack} = Equivalent crack radius, cm

η = A_{crack}/A_B, ($0 \leqq \eta \leqq 1$)

$$A_B \quad = \text{Area of the enclosed space below grade, cm}^2$$

$$X_{crack} \quad = \text{Floor-wall seam perimeter, cm.}$$

The variable r_{crack} is actually the product of the fixed crack-to-total area ratio (η) and the hydraulic radius of the idealized cylinder, which is equal to the total area (A_B) divided by that portion of the cylinder perimeter in contact with the soil gas (X_{crack}). Therefore, if the dimensions of the enclosed space below grade (A_B) and/or the floor-wall seam perimeter (X_{crack}) vary, and the crack-to-total area ratio (η) remains constant, the value of r_{crack} must also vary. The total area of cracks (A_{crack}) is the product of η and A_B.

Equation 15 requires that the soil column properties within the zone of influence of the building (e.g., porosities, bulk density, etc.) be homogeneous, that the soil be isotropic with respect to vapor permeability, and that the pressure within the building be less than atmospheric.

Equation 13 contains the exponent of the following dimensionless group:

$$\left(\frac{Q_{soil} \, L_{crack}}{D^{crack} \, A_{crack}} \right) \quad . \tag{17}$$

This dimensionless group represents the equivalent Peclet number for transport through the building foundation. As the value of this group approaches infinity, the value of α approaches:

$$\frac{\left(\dfrac{D_T^{eff} \, A_B}{Q_{building} \, L_T} \right)}{\left(\dfrac{D_T^{eff} \, A_B}{Q_{soil} \, L_T} \right) + 1} \quad . \tag{18}$$

In the accompanying spreadsheets, if the exponent of Equation 17 is too great to be calculated, the value of α is set equal to Equation 18.

With a calculated value of α, the steady-state vapor-phase concentration of the contaminant in the building ($C_{building}$) is calculated as:

$$C_{building} = \alpha \, C_{source} \quad . \tag{19}$$

2.6 THE FINITE SOURCE SOLUTION TO CONVECTIVE AND DIFFUSIVE TRANSPORT

If the thickness of soil contamination is known, the finite source solution of J&E (1991) can be employed such that the time-averaged attenuation coefficient ($\langle\alpha\rangle$) may be calculated as:

$$\langle\alpha\rangle = \frac{\rho_b \, C_R \, \Delta H_c \, A_B}{Q_{building} \, C_{source} \, \tau}\left(\frac{L_T^0}{\Delta H_c}\right)\left[\left(\beta^2 + 2\,\Psi\,\tau\right)^{1/2} - \beta\right] \qquad (20)$$

where

$\langle\alpha\rangle$ = Time-averaged finite source attenuation coefficient, unitless

ρ_b = Soil dry bulk density at the source of contamination, g/cm^3

C_R = Initial soil concentration, g/g

ΔH_c = Initial thickness of contamination, cm

A_B = Area of enclosed space below grade, cm^2

$Q_{building}$ = Building ventilation rate, cm^3/s

C_{source} = Vapor concentration at the source of contamination, g/cm^3-v

τ = Exposure interval, s

L_T^0 = Source-building separation at time = 0, cm

and;

$$\beta = \left(\frac{D_T^{eff} \, A_B}{L_T^O \, Q_{soil}}\right)\left[1 - \exp\left(-\frac{Q_{soil} \, L_{crack}}{D^{crack} \, A_{crack}}\right)\right] + 1 \qquad (21)$$

and;

$$\Psi = \frac{D_T^{eff} \, C_{source}}{\left(L_T^O\right)^2 \, \rho_b \, C_R} \qquad . \qquad (22)$$

Implicit in Equation 20 is the assumption that source depletion occurs from the top boundary of the contaminated zone as contaminant volatilizes and moves upward toward the soil surface. This creates a hypothetical "dry zone" (δ) that grows with time; conversely, the "wet zone" of contamination retreats proportionally. When the thickness of the depletion zone (δ) is equal to the initial thickness of contamination (ΔH_c), the source is totally depleted. The unitless expression $(L_T^0/\Delta H_c)[(\beta^2 + 2\,\Psi\tau)^{1/2} - \beta]$ in Equation 20 represents the cumulative fraction of the depletion zone at the end of the exposure interval τ. Multiplying this expression by the remainder of Equation 20 results in the time-averaged finite source attenuation coefficient ($<\alpha>$).

With a calculated value for $<\alpha>$, the time-averaged vapor concentration in the building ($C_{building}$) is:

$$C_{building} = \langle \alpha \rangle C_{source} \quad . \tag{23}$$

For extended exposure intervals (e.g., 30 years), the time for source depletion may be less than the exposure interval. The time for source depletion τ_D) may be calculated by:

$$\tau_D = \frac{\left[\Delta H_c / L_T^O + \beta\right]^2 - \beta^2}{2\,\Psi} \quad . \tag{24}$$

If the exposure interval (τ) is greater than the time for source depletion τ_D), the time-averaged building vapor concentration may be calculated by a mass balance such that:

$$C_{building} = \frac{\rho_b\, C_R\, \Delta H_c\, A_B}{Q_{building}\,\tau} \tag{25}$$

where

$C_{building}$ = Time-averaged vapor concentration in the building, g/cm^3-v

ρ_b = Soil dry bulk density at the source of contamination, g/cm^3

C_R = Initial soil concentration, g/g

ΔH_c = Initial thickness of contamination, cm

A_B = Area of enclosed space below grade, cm^2

$Q_{building}$ = Building ventilation rate, cm^3/s

τ = Exposure interval, s.

2.7   THE SOIL GAS MODELS

Use of the J&E Model has typically relied on a theoretical partitioning of the total volume soil concentration into the sorbed, aqueous, and vapor phases. The model has also relied on a theoretical approximation of vapor transport by diffusion and convection from the source of emissions to the building floor in contact with the soil. Use of measured soil gas concentrations directly beneath the building floor instead of theoretical vapor concentrations and vapor transport has obvious advantages that would help to reduce the uncertainty in the indoor air concentration estimates made by the model.

The soil gas models (SG-SCREEN and SG-ADV) are designed to allow the user to input measured soil gas concentration and sampling depth information directly into the spreadsheets. In the new models, the value of the user-defined soil gas concentration is assigned as the value of C_{source} in Equation 19. The steady-state (infinite source) attenuation coefficient (α) in Equation 19 is calculated using Equation 13. The steady-state solution for the attenuation coefficient is used because no evaluation has been made regarding the size and total mass of the source of emissions. The source of emissions, therefore, cannot be depleted over time. The soil gas models estimate the steady-state indoor air concentration over the exposure duration. For a detailed discussion of using the soil gas models as well as soil gas sampling, see Section 4 of this document.

2.8   SOIL VAPOR PERMEABILITY

Soil vapor permeability (k_v) is one of the most sensitive model parameters associated with convective transport of vapors within the zone of influence of the building. Soil vapor permeability is typically measured from field pneumatic tests. If field data are lacking, however, an estimate of the value of k_v can be made with limited data.

Soil intrinsic permeability is a property of the medium alone that varies with the size and shape of connected soil pore openings. Intrinsic permeability (k_i) can be estimated from the soil saturated hydraulic conductivity:

$$k_i = \frac{K_s \mu_w}{\rho_w\, g} \qquad\qquad (26)$$

where k_i = Soil intrinsic permeability, cm^2

K_s = Soil saturated hydraulic conductivity, cm/s

μ_w = Dynamic viscosity of water, g/cm-s (= 0.01307 at 10^oC)

ρ_w = Density of water, g/cm^3 (= 0.999)

g   = Acceleration due to gravity, cm/s^2 (= 980.665).

Schaap and Leij (1998) computed the SCS class average values of the saturated hydraulic conductivity (K_s) for each of the 12 SCS soil textural classifications (Table 5). With these values, a general estimate of the value of k_i can be made by soil type. As an alternative, in situ measurements of the site-specific saturated hydraulic conductivity can be made and the results input into Equation 26 to compute the value of the soil intrinsic permeability.

Effective permeability is the permeability of the porous medium to a fluid when more than one fluid is present; it is a function of the degree of saturation. The relative air permeability of soil (k_{rg}) is the effective air permeability divided by the intrinsic permeability and therefore takes into account the effects of the degree of water saturation on air permeability.

TABLE 5. CLASS AVERAGE VALUES OF SATURATED HYDRAULIC CONDUCTIVITY
FOR THE 12 SCS SOIL TEXTURAL CLASSIFICATIONS

Soil texture , USDA	Class average saturated hydraulic conductivity, cm/h
Sand	26.78
Loamy sand	4.38
Sandy loam	1.60
Sandy clay loam	0.55
Sandy clay	0.47
Loam	0.50
Clay loam	0.34
Silt loam	0.76
Clay	0.61
Silty clay loam	0.46
Silt	1.82
Silty clay	0.40

Parker et al. (1987) extended the relative air permeability model of van Genuchten (1980) to allow estimation of the relative permeabilities of air and water in a two- or three-phase system:

$$k_{rg} = \left(1 - S_{te}\right)^{1/2} \left(1 - S_{te}^{1/M}\right)^{2M} \tag{27}$$

where k_{rg} = Relative air permeability, unitless ($0 \leq k_{rg} \leq 1$)

              S_{te} = Effective total fluid saturation, unitless

              M = van Genuchten shape parameter, unitless.

Given a two-phase system (i.e., air and water), the effective total fluid saturation (S_{te}) is calculated as:

$$S_{te} = \frac{(\theta_w - \theta_r)}{(n - \theta_r)} \qquad (28)$$

where S_{te} = Effective total fluid saturation, unitless

                θ_w = Soil water-filled porosity, cm^3/cm^3

                θ_r = Residual soil water content, cm^3/cm^3

                n   = Soil total porosity, cm^3/cm^3.

Class average values for the parameters θ_r and M by SCS soil type may be obtained from Table 3.

The effective air permeability (k_v) is then the product of the intrinsic permeability (k_i) and the relative air permeability (k_{rg}) at the soil water-filled porosity θ_w.

2.9   CALCULATION OF A RISK-BASED SOIL OR GROUNDWATER CONCENTRATION

Both the infinite source model estimate of the steady-state building concentration and the finite source model estimate of the time-averaged building concentration represent the exposure point concentration used to assess potential risks. Calculation of a risk-based media concentration for a carcinogenic contaminant takes the form:

$$C_C = \frac{TR \, x \, AT_C \, x \, 365 \, days/yr}{URF \, x \, EF \, x \, ED \, x \, C_{building}} \qquad (29)$$

where C_C = Risk-based media concentration for carcinogens, µg/kg-soil, or µg/L-water

                TR   = Target risk level, unitless

                AT_C = Averaging time for carcinogens, yr

                URF   = Unit risk factor, $µg/m^3)^{-1}$

                EF   = Exposure frequency, days/yr

                ED   = Exposure duration, yr

$C_{building}$ = Vapor concentration in the building, µg/m³ per µg/kg-soil,
or µg/m³ per µg/L-water.

In the case of a noncarcinogenic contaminant, the risk-based media concentration is calculated by:

$$C_{NC} = \frac{THQ \times AT_{NC} \times 365\,days/yr}{EF \times ED \times \dfrac{1}{RfC} \times C_{building}} \qquad (30)$$

where C_{NC} = Risk-based media concentration for noncarcinogens, µg/kg-soil, or µg/L-water

                     THQ   = Target hazard quotient, unitless

                     AT_{NC} = Averaging time for noncarcinogens, yr

                     EF   = Exposure frequency, days/yr

                     ED   = Exposure duration, yr

                     RfC   = Reference concentration, mg/m³

                     $C_{building}$ = Vapor concentration in the building, mg/m³ per µg/kg-soil, or mg/m³ per µg/L-water.

The spreadsheets calculate risk-based media concentrations based on a unity initial concentration. That is, soil risk-based concentrations are calculated with an initial hypothetical soil concentration of 1 µg/kg-soil, while for groundwater the initial hypothetical concentration is 1 µg/L-water.

For this reason, the values of C_{source} and $C_{building}$ shown on the INTERCALCS worksheet when reverse-calculating a risk-based media concentration do not represent actual values. For these calculations, the following message will appear on the RESULTS worksheet:

"MESSAGE: The values of C_{source} and $C_{building}$ on the INTERCALCS worksheet are based on unity and do not represent actual values."

When forward-calculating risks from a user-defined initial soil or groundwater concentration, the values of C_{source} and $C_{building}$ on the INTERCALCS worksheet are correct.

2.10   CALCULATION OF INCREMENTAL RISKS

Forward-calculation of incremental risks begins with an actual initial media concentration (i.e., μg/kg-soil or μg/L-water). For carcinogenic contaminants, the risk level is calculated as:

$$Risk = \frac{URF \; x \; EF \; x \; ED \; x \, C_{building}}{AT_C \; x \, 365 \, days \, / \, yr} \qquad (31)$$

For noncarcinogenic contaminants, the hazard quotient (HQ) is calculated as:

$$HQ = \frac{EF \; x \; ED \; x \, \dfrac{1}{RfC} \; x \; C_{building}}{AT_{NC} \; x \; 365 \; days \, / \, yr} \qquad . \qquad (32)$$

2.11   MAJOR MODEL ASSUMPTIONS/LIMITATIONS

The following represent the major assumptions/limitations of the J&E Model.

1.   Contaminant vapors enter the structure primarily through cracks and openings in the walls and foundation.

2.   Convective transport occurs primarily within the building zone of influence and vapor velocities decrease rapidly with increasing distance from the structure.

3.   Diffusion dominates vapor transport between the source of contamination and the building zone of influence.

4.   All vapors originating from below the building will enter the building unless the floors and walls are perfect vapor barriers.

5.   All soil properties in any horizontal plane are homogeneous.

6.   The contaminant is homogeneously distributed within the zone of contamination.

7.   The areal extent of contamination is greater than that of the building floor in contact with the soil.

8.   Vapor transport occurs in the absence of convective water movement within the soil column (i.e., evaporation or infiltration), and in the absence of mechanical dispersion.

9.   The model does not account for transformation processes (e.g., biodegradation, hydrolysis, etc.).

10. The soil layer in contact with the structure floor and walls is isotropic with respect to permeability.

11. Both the building ventilation rate and the difference in dynamic pressure between the interior of the structure and the soil surface are constant values.

Use of the J&E Model as a first-tier screening tool to identify sites needing further assessment requires careful evaluation of the assumptions listed in the previous section to determine whether any conditions exist that would render the J&E Model inappropriate for the site. If the model is deemed applicable at the site, care must be taken to ensure reasonably conservative and self-consistent model parameters are used as input to the model. Considering the limited site data typically available in preliminary site assessments, the J&E Model can be expected to predict only whether or not a risk-based exposure level will be exceeded at the site. Precise prediction of concentration levels is not possible with this approach.

The suggested minimum site characterization information for a first tier evaluation of the vapor intrusion pathway includes: site conceptual model, nature and extent of contamination distribution, soil lithologic descriptions, groundwater concentrations, and/or possibly near source soil vapor concentrations. The number of samples and measurements needed to establish this information varies by site and it's not possible to provide a hard and fast rule. Bulk soil concentrations should not be used unless appropriately preserved during sampling.

Based on the conceptual site model (CSM), the user can select the appropriate spreadsheet corresponding to the vapor source at the site and determine whether to use the screening level spreadsheet (which allows only one soil type above the capillary fringe) or the more advanced version (which allows up to three layers above the capillary fringe). Because most of the inputs to the J&E Model are not collected during a typical site characterization, conservative inputs have to be estimated or inferred from available data and other non-site-specific sources of information.

The uncertainty in determining key model parameters and sensitivity of the J&E Model to those key model parameters is qualitatively described in Table 6. As shown in the table, building-related parameters will moderate to high uncertainty and model sensitivity include: Qsoil, building crack ratio, building air-exchange rate, and building mixing height. Building-related parameters with low uncertainty and sensitivity include: foundation area, depth to base of foundation, and foundation slab thickness. Of the soil-dependent properties, the soil moisture parameters clearly are of critical importance for the attenuation value calculations.

TABLE 6. UNCERTAINTY AND SENSITIVITY OF KEY PARAMETERS FOR THE VAPOR INTRUSION MODEL

Input Parameter	Parameter Uncertainty Or Variability	Parameter Sensitivity			
		Shallower Contamination Building Underpressurized	Deeper Contamination Building Underpressurized	Shallower Contamination Building Not Underpressurized	Deeper Contamination Building Not Underpressurized
Soil Total Porosity (n)	Low	Low	Low	Low	Low
Soil Water-filled Porosity (θ_w)	Moderate to High	Low to Moderate	Moderate to High	Moderate to High	Moderate to High
Capillary Zone Water-filled Porosity ($\theta_{n, cz}$)	Moderate to High	Moderate to High	Moderate to High	Moderate to High	Moderate to High
Thickness of Capillary Zone (L_{cz})	Moderate to High	Moderate to High	Moderate to High	Moderate to High	Moderate to High
Soft Dry Bulk Density (ρ_b)	Low	Low	Low	Low	Low
Average Vapor Flowrate into a Building (Q_{soil})	High	Moderate to High	Low to Moderate	N/A	N/A
Soil Vapor Permeability(K_v)	High	Moderate to High	Low to Moderate	N/A	N/A
Soil to Building Pressure Differential (ΔP)	Moderate	Moderate	Low to Moderate	N/A	N/A
Henry's Law Constant (for single chemical) (H)	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate
Diffusivity in Air (D_A)	Low	Low	Low	Low	Low
Indoor Air Exchange Rate (ER)	Moderate	Moderate	Moderate	Moderate	Moderate
Enclosed Space Height (H_B)	Moderate	Moderate	Moderate	Moderate	Moderate
Area of Enclosed Space Below Grade (A_B)	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate
Depth Below Grade to Bottom of Enclosed Space (L_F)	Low	Low	Low	Low	Low
Crack-to-Total Area Ratio (η)	High	Low	Low	Moderate to High	Low to Moderate
Enclosed Space Floor Thickness (L_{crack})	Low	Low	Low	Low	Low

SECTION 3

SOIL AND GROUNDWATER MODEL APPLICATION

This section provides step-by-step instructions on how to implement the soil and groundwater contamination versions of the J&E Model using the spreadsheets. This section also discusses application of the soil gas versions of the model. The user provides data and selects certain input options, and views model results via a series of worksheets. Error messages are provided within both the data entry worksheet and the results worksheet to warn the user that entered data are missing or outside of permitted limits.

The J&E Model as constructed within the accompanying spreadsheets requires a range of input variables depending on whether a screening-level or advanced model is chosen. Table 7 provides a list of all major input variables, the range of practical values for each variable, the default value for each variable, and the relative model sensitivity and uncertainty of each variable. Table 7 also includes references for each value or range of values.

Table 8 indicates the results of an increase in the value of each input parameter. The results are shown as either an increase or a decrease in the building concentration ($C_{building}$) of the pollutant. An increase in the building concentration will result in an increase in the risk when forward-calculating from an initial soil or groundwater concentration. When reverse-calculating to a risk-based "acceptable" soil or groundwater concentration, an increase in the hypothetical unit building concentration will result in a lower "acceptable" soil or groundwater concentration.

A list of reasonably conservative model input parameters for building-related parameters is provided in Table 9, which also provides the practical range, typical or mean value (if applicable), and most conservative value for these parameters. For building parameters with low uncertainty and sensitivity, only a single "fixed" value corresponding to the mean or typical value is provided in Table 9. Soil-dependent properties are provided in Table 10 for soils classified according to the US SCS system. If site soils are not classified according to the US SCS, Table 11 can be used to assist in selecting an appropriate SCS soil type corresponding to the available site lithologic information. Note that the selection of the soil texture class should be biased towards the coarsest soil type of significance, as determined by the site characterization program.

TABLE 7. RANGE OF VALUES FOR SELECTED INPUT PARAMETERS

Input parameter	Practical range of values	Default value
Soil water-filled porosity (θ_w)	0.02 – 0.43 cm^3/cm^{3a}	0.30 cm^3/cm^{3a}
Soil vapor permeability (k_v)	10^{-6} – 10^{-12} cm^{2b,c}	10^{-8} cm^{2d}
Soil-building pressure differential (ΔP)	0 – 20 Pa^3	4 Pa^f
Media initial concentration (C_R, C_w)	User-defined	NA
Depth to bottom of soil contamination (L_b)	User-defined	NA
Depth to top of concentration (L_T)	User-defined	NA
Floor-wall seam gap (w)	0.05 – 1.0 cm^e	0.1 cm^e
Soil organic carbon fraction (f_{oc})	0.001 – 0.006^a	0.002^a
Indoor air exchange rate (ER)	0.18 – 1.26 (H^{-1})^g	0.25 (h^{-1})^{g,h}
Soil total porosity (n)	0.34 – 0.53 cm^3/cm^{3a}	0.43 cm^3/cm^{3a}
Soil dry bulk density (ρ_b)	1.25 – 1.75 g/cm^{3a}	1.5 g/cm^{3a}

[a] U.S. EPA (1996a and b).

[b] Johnson and Ettinger (1991).

[c] Nazaroff (1988).

[d] Based on transition point between diffusion and convection dominated transport from Johnson and Ettinger (1991).

[e] Eaton and Scott (1984); Loureiro et al. (1990).

[f] Loureiro et al. (1990); Grimsrud et al. (1983).

[g] Koontz and Rector (1995).

[h] Parker et al. (1990).

[i] U.S. DOE (1995).

TABLE 8. EFFECT ON BUILDING CONCENTRATION FROM AN INCREASE IN INPUT PARAMETER VALUES

Input parameter	Change in parameter value	Effect on building concentration
Soil water-filled porosity (θ_w)	Increase	Decrease
Soil vapor permeability (k_v)	Increase	Increase
Soil-building pressure differential (ΔP)	Increase	Increase
Media initial concentration (C_R, C_w)[a]	Increase	Increase
Depth to bottom of soil contamination (L_b)[b]	Increase	Increase
Depth to top of concentration (L_T)	Increase	Decrease
Floor-wall seam gap (w)	Increase	Increase
Soil organic carbon fraction (f_{oc})	Increase	Decrease
Indoor air exchange rate (ER)	Increase	Decrease
Building volume[c] (L_B x W_B x H_B)	Increase	Decrease
Soil total porosity (n)	Increase	Increase
Soil dry bulk density (ρ_b)	Increase	Decrease

[a] This parameter is applicable only when forward-calculating risk.

[b] Applicable only to advanced model for soil contamination.

[c] Used with building air exchange rate to calculate building ventilation rate.

TABLE 9. BUILDING-RELATED PARAMETERS FOR THE VAPOR INTRUSION MODEL

Input Parameter	Units	Fixed or Variable	Typical or Mean Value	Range	Conservative Value	Default Value
Total Porosity	cm^3/cm^3	Fixed	Specific to soil texture, see Table 10			
Unsaturated Zone Water-filled Porosity	cm^3/cm^3	Variable	Specific to soil texture, see Table 10			
Capillary Transition zone Water-filled Porosity	cm^3/cm^3	Fixed	Specific to soil texture, see Table 10			
Capillary Transition Zone height	cm^3/cm^3	Fixed	Specific to soil texture, see Table 10			
Q_{soil}	L/min	Variable	Specific to soil texture, see Table 10			
Soil air permeability	m^2	Variable	Specific to soil texture, see Table 10			
Building Depressurization	Pa	Variable	4	0-15	15	N/A
Henry's law constant (for single chemical)	-	Fixed	Specific to chemical, see Appendix B			
Free-Air Diffusion Coefficient (single chemical)	-	Fixed	Specific to chemical, see Appendix B			
Building Air exchange Rate	hr^{-1}	Variable	0.5	0.1-1.5	0.1	0.25
Building Mixing height – Basement scenario	m	Variable	3.66	2.44-4.88	2.44	3.66
Building Mixing height – Slab-on-grade scenario	m	Variable	2.44	2.13-3.05	2.13	2.44
Building Footprint Area – Basement Scenario	m^2	Variable	120	80-200+	80	100
Building Footprint Area – Slab-on-Grade Scenario	m^2	Variable	120	80-200+	80	100
Subsurface Foundation area – Basement Scenario	m^2	Variable	208	152-313+	152	180
Subsurface Foundation area – Slab-on-Grade Scenario	m^2	Fixed	127	85-208+	85	106
Depth to Base of Foundation – Basement Scenario	m	Fixed	2	N/A	N/A	2
Depth to Base of Foundation – Slab-on-Grade Scenario	m	Fixed	0.15	N/A	N/A	0.15
Perimeter Crack Width	mm	Variable	1	0.5-5	5	1
Building Crack ratio – Slab-on-Grade Scenario	dimensionless	Variable	0.00038	0.00019-0.0019	0.0019	3.77×10^{-4}
Building Crack ratio – Basement Scenario	dimensionless	Variable	0.0002	0.0001-0.001	0.001	2.2×10^{-4}
Crack Dust Water-Filled Porosity	cm^3/cm^3	Fixed	Dry	N/A	N/A	Dry
Building Foundation Slab Thickness	m	Fixed	0.1	N/A	N/A	0.1

TABLE 10. SOIL-DEPENDENT PROPERTIES FOR THE VAPOR INTRUSION MODEL - FIRST TIER ASSESSMENT

U.S. Soil Conservation Service (SCS) Soil Texture	Saturated Water Content Total Porosity θ_s (cm³/cm³)	Residual Water Content θ_r (cm³/cm³)	Unsaturated Zone Water-Filled Porosity Mean or Typical (FC$_{1/3bar}$+θ_r)/2 $\theta_{w,unsat}$ (cm³/cm³)	Range $\theta_{w,unsat}$ (cm³/cm³)	Conservative $\theta_{w,unsat}$ (cm³/cm³)	Modeled $\theta_{w,unsat}$ (cm³/cm³)	Capillary Transition Zone Saturated Water Content Total Porosity θ_s (cm³/cm³)	$\theta_{w,cap}$ Cap @ air-entry	Height Cap Zone Fetter (94) (cm)
Clay	0.459	0.098	0.215	0.098-0.33	0.098	0.215	0.459	0.412	81.5
Clay Loam	0.442	0.079	0.168	0.079-0.26	0.079	0.168	0.442	0.375	46.9
Loam	0.399	0.061	0.148	0.061-0.24	0.061	0.148	0.399	0.332	37.5
Loamy Sand	0.39	0.049	0.076	0.049-0.1	0.049	0.076	0.39	0.303	18.8
Silt	0.489	0.05	0.167	0.05-0.28	0.050	0.167	0.489	0.382	163.0
Silt Loam	0.439	0.065	0.180	0.065-0.3	0.065	0.180	0.439	0.349	68.2
Silty Clay	0.481	0.111	0.216	0.11-0.32	0.111	0.216	0.481	0.424	192.0
Silty Clay Loam	0.482	0.09	0.198	0.09-0.31	0.090	0.198	0.482	0.399	133.9
Sand	0.375	0.053	0.054	0.053-0.055	0.053	0.054	0.375	0.253	17.0
Sandy Clay	0.385	0.117	0.197	0.117-0.28	0.117	0.197	0.385	0.355	30.0
Sandy Clay Loam	0.384	0.063	0.146	0.063-0.23	0.063	0.146	0.384	0.333	25.9
Sandy Loam	0.387	0.039	0.103	0.039-0.17	0.039	0.103	0.387	0.320	25.0
Loamy Sand	0.39	0.049	0.076	0.049-0.1	0.049	0.076	0.39	0.303	18.8

TABLE 11. GUIDANCE FOR SELECTION OF SOIL TYPE

If your boring log indicates that the following materials are the predominant soil types …	Then you should use the following texture classification when obtaining the attenuation factor
Sand or Gravel or **Sand and Gravel**, with less than about 12 % fines, where "fines" are smaller than 0.075 mm in size.	Sand
Sand or Silty Sand, with about 12 % to 25 % fines	Loamy Sand
Silty Sand, with about 20 % to 50 % fines	Sandy Loam
Silt and Sand or Silty Sand or Clayey, Silty Sand or Sandy Silt or Clayey, Sandy Silt, with about 45 to 75 % fines	Loam
Sandy Silt or Silt, with about 50 to 85 % fines	Silt Loam

These input parameters were developed from the best available soil-physics science, available studies of building characteristics, and international-expert opinion. Consequently, the input parameters listed in Tables 9 and 10 are considered default parameters for a first-tier assessment, which should in most cases provide a reasonably (but not overly) conservative estimate of the vapor intrusion attenuation factor for a site. Justification for the building-related and soil-dependent parameters values selected as default values for the J&E Model is described below.

3.1 JUSTIFICATION OF DEFAULT SOIL-DEPENDENT PROPERTIES

The default soil-dependent parameters recommended for a first tier assessment (Table 10) represent mean or typical values, rather than the most conservative value, in order to avoid overly conservative estimates of attenuation factors. Note, however, that the range of values for some

soil properties can be very large, particularly in the case of moisture content and hydraulic conductivity. Consequently, selecting a soil type and corresponding typical soil property value may not accurately or conservatively represent a given site. Note also that Table 9 does not provide estimates of soil properties for very coarse soil types, such as gravel, gravelly sand, and sandy gravel, etc., which also may be present in the vadose zone. Consequently, in cases where the vadose zone is characterized by very coarse materials, the J&E Model may not provide a conservative estimate of attenuation factor.

As discussed above, the J&E Model is sensitive to the value of soil moisture content. Unfortunately, there is little information available on measured moisture contents below buildings. Therefore, the typical approach is to use a water retention model (e.g., van Genuchten model) to approximate moisture contents. For the unsaturated zone, the selected default value for soil moisture is a value equal to halfway between the residual saturation value and field capacity, using the van Genuchten model-predicted values for U.S. SCS soil types. For the capillary transition zone, a moisture content corresponding to the air entry pressure head is calculated by using the van Genuchten model. When compared to other available water retention models, the van Genuchten model yields somewhat lower water contents, which results in more conservative estimates of attenuation factor. The soil moisture contents listed in Table 10 are based on agricultural samples, which are likely to have higher water contents than soils below building foundations and, consequently result in less-conservative estimates of the attenuation factor.

3.2   JUSTIFICATION OF DEFAULT BUILDING-RELATED PROPERTIES

Building Air Exchange Rate (Default Value = 0.25 AEH)

The results of 22 studies for which building air exchange rates are reported in Hers et al. (2001). Ventilation rates vary widely from approximately 0.1 AEH for energy efficient "air-tight" houses (built in cold climates) (Fellin and Otson, 1996) to over 2 AEH (AHRAE (1985); upper range). In general, ventilation rates will be higher in summer months when natural ventilation rates are highest. Murray and Burmaster (1995) conducted one of the most comprehensive studies of U.S. residential air exchange rates (sample size of 2844 houses). The data set was analyzed on a seasonal basis and according to climatic region. When all the data were analyzed, the 10th, 50th and 90th percentile values were 0.21, 0.51 and 1.48 AEH. Air exchange rates varied depending on season and climatic region. For example, for the winter season and coldest climatic area (Region 1, e.g., Great Lakes area and extreme northeast U.S.), the 10th, 50th , and 90th percentile values were 0.11, 0.27 and 0.71 AEH, respectively.. In contrast, for the winter season and warmest climatic area [Region 4 (southern California, Texas, Florida, Georgia)], the 10th, 50th, and 90th percentile values were 0.24, 0.48 and 1.13 AEH, respectively. Although building air exchange rates would be higher during the summer months, vapor intrusion during winter months (when house depressurization is expected to be most significant) would be of greatest concern. For this guidance, a default value of 0.25 for air exchange rate was selected to represent the lower end of these distributions.

Crack Width and Crack Ratio (Default Value = 0.0002 for basement house; = 0.0038 for slab-on-grade house)

The crack width and crack ratio are related. Assuming a square house and that the only crack is a continuous edge crack between the foundation slab and wall ("perimeter crack"), the crack ratio and crack width are related as follows:

Crack Ratio = Crack Width x 4 x (Subsurface Foundation Area)^0.5/Subsurface Foundation Area

Little information is available on crack width or crack ratio. One approach used by radon researchers is to back-calculate crack ratios using a model for soil gas flow through cracks and the results of measured soil gas flow rates into a building. For example, the back-calculated values for a slab/wall edge crack based on soil gas-entry rates reported in Nazaroff (1992), Revzan *et al.* (1991), and Nazaroff *et al.* (1985) range from about 0.0001 to 0.001. Another possible approach is to measure crack openings although this, in practice, is difficult to do. Figley and Snodgrass (1992) present data from 10 houses where edge crack measurements were made. At the eight houses where cracks were observed, the crack widths ranged from hairline cracks up to 5 mm wide, while the total crack length per house ranged from 2.5 m to 17.3 m. Most crack widths were less than 1 mm. The suggested defaults for crack ratio in regulatory guidance, literature, and models also vary. In ASTM E1739-95, a default crack ratio of 0.01 is used. The crack ratios suggested in the VOLASOIL model (developed by the Dutch Ministry of Environment) range from 0.0001 to 0.000001. The VOLASOIL model values correspond to values for a "good" and "bad" foundation, respectively. The crack ratio used by J&E (1991) for illustrative purposes ranged from 0.001 to 0.01. The selected default values fall within the ranges observed.

Building Area and Subsurface Foundation Area (Default Value = 10 m by 10 m)

The default building area is based on the following information:

- Default values used in the Superfund User's Guide (9.61 m by 9.61 m or 92.4 m^2)
- Default values used by the State of Michigan, as documented in Part 201, Generic Groundwater and Soil Volatilization to Indoor Air Inhalation Criteria: Technical Support Document (10.5 m by 10.5 m of 111.5 m^2).

The Michigan guidance document indicates that the 111.5 m^2 area approximately corresponds to the 10th percentile floor space area for a residential single-family dwelling, based on statistics compiled by the U.S. Department of Commerce (DOC) and U.S. Housing and Urban Development (HUD). The typical, upper, and lower ranges presented in Table 9 are subjectively chosen values. The subsurface foundation area is a function of the building area, and depth to the base of the foundation, which is fixed.

Building Mixing Height (Default Value = 2.44 m for slab-on-grade scenario; = 3.66 m for basement scenario)

The J&E Model assumes that subsurface volatiles migrating into the building are completely mixed within the building volume, which is determined by the building area and mixing height. The building mixing height will depend on a number of factors including building height; heating, ventilation, and air conditioning (HVAC) system operation, environmental factors such as indoor-outdoor pressure differentials and wind loading, and seasonal factors. For a single-story house, the variation in mixing height can be approximated by using the room height. For a multi-story house or apartment building, the mixing height will be greatest for houses with HVAC systems that result in significant air circulation (e.g., forced-air heating systems). Mixing heights would likely be less for houses with electrical baseboard heaters. It is likely that mixing height is, to some degree, correlated to the building air exchange rate.

Little data are available that provides for direct inference of mixing height. There are few sites, with a small number of houses where indoor air concentrations were above background, and where both measurements at ground level and the second floor were made Colorado Department of Transportation (CDOT), Redfields, Eau Claire). Persons familiar with the data sets for these sites indicate that in most cases a fairly significant reduction in concentrations (factor of two or greater) was observed, although at one site (Eau Claire, "S" residence), the indoor trichloroethylene (TCE) concentrations were similar in both the basement and second floor of the house. For the CDOT site apartments, there was an approximate five-fold reduction between the concentrations measured for the first floor and second floor units (Mr. Jeff Kurtz, EMSI, personal communication, June 2002). Less mixing would be expected for an apartment because there are less cross-floor connections than for a house. The value chosen for a basement house scenario (3.66 m) would be representative of a two-fold reduction or attenuation in vapor concentrations between floors.

Q_{soil} (Default Value = 5 L/min)

The method often used with the J&E Model for estimating the soil gas advection rate (Q_{soil}) through the building envelope is an analytical solution for two-dimensional soil gas flow to a small horizontal drain (Nazaroff 1992) ("Perimeter Crack Model"). Use of this model can be problematic in that Q_{soil} values are sensitive to soil-air permeability and consequently a wide range in flows can be predicted.

An alternate empirical approach is to select a Q_{soil} value on the basis of tracer tests (i.e., mass balance approach). When soil gas advection is the primary mechanism for tracer intrusion into a building, the Q_{soil} can be estimated by measuring the concentrations of a chemical tracer in indoor air, in outdoor air, and in soil vapor below a building, and by measuring the building ventilation rate (Hers et al. 2000a; Fischer et al. 1996; Garbesi et al. 1993; Rezvan et al. 1991; Garbesi and Sextro, 1989). For sites with coarse-grained soils (Table 10). The Q_{soil} values measured using this technique are compared to predicted rates using the Perimeter Crack model. The Perimeter Crack model predictions are both higher and lower than the measured values, but overall are within one order of magnitude of the measured values. Although the Q_{soil} values predicted by the models and measured

using field tracer tests are uncertain, the results suggest that a "typical" range for houses on coarse-grained soils is on the order of 1 to 10 L/min. A disadvantage with the tracer test approach is that only limited data are available and there do not appear to be any tracer studies for field sites with fine-grained soils.

It is also important to recognize that the advective zone of influence for soil gas flow is limited to soil immediately adjacent to the building foundation. Some data on pressure coupling provide insight on the extent of the advective flow zone. For example, Garbesi *et al.* (1993) report a pressure coupling between the soil and experimental basement (*i.e.*, relative to that between the basement and atmosphere) equal to 96 percent directly below the slab, between 29 percent and 44 percent at 1 m below the basement floor slab, and between 0.7 percent and 27 percent at a horizontal distance of 2 m from the basement wall. At the Chatterton site (research site investigated by the author), the pressure coupling immediately below the building floor slab ranged from 90 to 95 percent and at a depth of 0.5 m was on the order of 50 percent. These results indicate that the advective zone of influence will likely be limited to a zone within 1 to 2 m of the building foundation.

Because the advective flow zone is relatively limited in extent, the soil type adjacent to the building foundation is of importance. In many cases, coarse-grained imported fill is placed below foundations, and either coarse-grained fill, or disturbed, loose fill is placed adjacent to the foundation walls. Therefore, a conservative approach for the purposes of this guidance is to assume that soil gas flow will be controlled by coarse-grained soil, and not rely on the possible reduction in flow that would be caused by fine-grained soils near to the house foundation. For these reasons, a soil gas flow rate of 5 L/min (midpoint between 1 and 10 L/min) was chosen as the input value.

3.3   RUNNING THE MODELS

Eight different models are provided in MICROSOFT EXCEL formats.

1.   Models for Soil Contamination:
        SL-SCREEN-Feb 03.XLS
        SL-ADV-Feb 03.XLS

2.   Models for Groundwater Contamination:
        GW-SCREEN-Feb 03.XLS
        GW-ADV-Feb 03.XLS

3.   Model for Soil Gas Contamination
        SG-SCREEN-Feb 03.xls
        SG-ADV-Feb 03.xls

4.   Models for Non Aqueous Phase Liquids
        NAPL-SCREEN-Feb 03.xls

NAPL-ADV-Feb 03.xls

Both the screening-level models and the advanced models allow the user to calculate a risk-based media concentration or incremental risks from an actual starting concentration in soil or in groundwater. Data entry within the screening-level models is limited to the most sensitive model parameters and incorporates only one soil stratum above the contamination. The advanced models provide the user with the ability to enter data for all of the model parameters and also incorporate up to three individual soil strata above the contamination for which soil properties may be varied.

To run any of the models, simply open the appropriate model file within MICROSOFT EXCEL. Each model is constructed of the following worksheets:

1.   DATENTER (Data Entry Sheet)
2.   CHEMPROPS (Chemical Properties Sheet)
3.   INTERCALCS (Intermediate Calculations Sheet)
4.   RESULTS (Results Sheet)
5.   VLOOKUP (Lookup Tables).

The following is an explanation of what is contained in each worksheet, how to enter data, how to interpret model results, and how to add/revise the chemical properties data found in the VLOOKUP Tables. As examples, Appendix C contains all the worksheets for the advanced soil contamination model SL-ADV.

3.4   THE DATA ENTRY SHEET (DATENTER)

Figure 4 is an example of a data entry sheet. In this case, it shows the data entry sheet for the screening-level model for contaminated groundwater (GW-SCREEN). Figure 5 is an example of an advanced model data entry sheet (GW-ADV). Note that the screening-level model sheet requires entry of considerably less data than does the advanced sheet. To enter data, simply position the cursor within the appropriate box and type the value; all other cells are protected.

Error Messages

In the case of the screening-level models, all error messages will appear in red type below the applicable row of data entry boxes. For the advanced models, error messages may appear on the data entry sheet or in the lower portion of the results sheet. Error messages will occur if required entry data are missing or if data are out of range or do not conform to model conventions. The error message will tell the user what kind of error has occurred.

GW-SCREEN
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES | X |

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES | |

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W ($\mu g/L$)	Chemical
56235		Carbon tetrachloride

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
200	400	SC	10	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SC			SC	1.3	0.385	0.197

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-05	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

END

Figure 4. GW-SCREEN Data Entry Sheet

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CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)
YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)
YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes) — 56235

ENTER Initial groundwater conc., C_w (µg/L)

Chemical: **Carbon tetrachloride**

Field	Value
ENTER Average soil/groundwater temperature, T_s (°C)	10
ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	200
ENTER Depth below grade to water table, L_{WT} (cm)	400
ENTER Thickness of soil stratum A, h_A (cm)	300
ENTER Thickness of soil stratum B, h_B (cm)	50
ENTER Thickness of soil stratum C, h_C (Enter value or 0) (cm)	50
(Totals must add up to value of L_{WT} (cell F28))	
ENTER Soil stratum directly above water table, (Enter A, B, or C)	C
SCS soil type directly above water table	SC
ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	C
OR	
ENTER User-defined stratum A soil vapor permeability, k_v (cm²)	

MORE →

Field	Value
ENTER Stratum A SCS soil type [Lookup Soil Parameters]	C
ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)	1.20
ENTER Stratum A soil total porosity, n^A (unitless)	0.459
ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	0.215
ENTER Stratum B SCS soil type [Lookup Soil Parameters]	S
ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	1.65
ENTER Stratum B soil total porosity, n^B (unitless)	0.375
ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	0.054
ENTER Stratum C SCS soil type [Lookup Soil Parameters]	SC
ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	1.3
ENTER Stratum C soil total porosity, n^C (unitless)	0.385
ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)	0.197

MORE →

Field	Value
ENTER Enclosed space floor thickness, L_{crack} (cm)	10
ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)	40
ENTER Enclosed space floor length, L_B (cm)	1000
ENTER Enclosed space floor width, W_B (cm)	1000
ENTER Enclosed space height, H_B (cm)	366
ENTER Floor-wall seam crack width, w (cm)	0.1
ENTER Indoor air exchange rate, ER (1/h)	0.25
ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)	5

MORE →

Field	Value
ENTER Averaging time for carcinogens, AT_c (yrs)	70
ENTER Averaging time for noncarcinogens, AT_{nc} (yrs)	30
ENTER Exposure duration, ED (yrs)	30
ENTER Exposure frequency, EF (days/yr)	350
ENTER Target risk for carcinogens, TR (unitless)	1.0E-05
ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	1

Used to calculate risk-based groundwater concentration.

END

Figure 5. GW-ADV Data Entry Sheet

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Figure 6 is an example of an error message appearing on the data entry sheet. Figure 7 illustrates error messages appearing within the message and error summary section on the results sheet (advanced models only).

Entering Data

Each data entry sheet requires the user to input values for model variables. Data required for the soil contamination scenario will differ from that required for the groundwater contamination scenario. In addition, data required for the screening-level models will differ from that required for the advanced models.

Model Variables--

The following is a list of all data entry variables required for evaluating either a risk-based media concentration or the incremental risks due to actual contamination. A description for which model(s) the variable is appropriate is given in parenthesis after the name of the variable. In addition, notes on how the variable is used in the calculations and how to determine appropriate values of the variable are given below the variable name. A quick determination of which variables are required for a specific model can be made by reviewing the data entry sheet for the model chosen. Example data entry sheets for each model can be found in Appendix D.

1. *Calculate Risk-Based Concentration* or *Calculate Incremental Risks from Actual Concentration* (All Soil and Groundwater Models)

    The model will calculate either a risk-based soil or groundwater concentration or incremental risks but cannot calculate both simultaneously. Enter an "X" in only one box.

2. *Chemical CAS No.* (All Models)

    Enter the appropriate CAS number for the chemical you wish to evaluate; do not enter dashes. The CAS number entered must exactly match that of the chemical, or the error message "CAS No. not found" will appear in the "Chemical" box. Once the correct CAS number is entered, the name of the chemical will automatically appear in the "Chemical" box. A total of 108 chemicals and their associated properties are included with each model; see Section 3.7 for instructions on adding/revising chemicals.

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

| ENTER | ENTER Initial | |
Chemical CAS No. (numbers only, no dashes)	groundwater conc., C_W (µg/L)	Cannot calculate risk-based concentration and incremental risk simultaneously. Chemical
56235		Carbon tetrachloride

Figure 6. Example Error Message on Data Entry Sheet

RISK-BASED SOIL CONCENTRATION CALCULATIONS: INCREMENTAL RISK CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)	Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA	NA	4.81E+05	NA	2.9E-05	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

ERROR: Combined thickness of strata A + B + C must be = depth below grade to top of contamination.

Figure 7. Example Error Message on Results Sheet

3. *Initial Soil or Groundwater Concentration* (All Soil and Groundwater Models) (L_w)

Enter a value only if incremental risks are to be calculated. Be sure to enter the concentration in units of µg/kg (wet weight basis soil) or µg/L (groundwater). Typically, this value represents the average concentration within the zone of contamination. If descriptive statistics are not available to quantify the uncertainty in the average value, the maximum value may be used as an upper bound estimate.

4. *Average Soil/Groundwater Temperature* (All Models) (T_s)

The soil/groundwater temperature is used to correct the Henry's law constant to the specified temperature. Figure 8 from U.S. EPA (1995) shows the average temperature of shallow groundwater in the continental United States. Shallow groundwater temperatures may be used to approximate subsurface soil temperatures greater than 1 to 2 meters below the ground surface. Another source of information may be your State groundwater protection regulatory agency.

5. *Depth Below Grade to Bottom of Enclosed Space Floor* (All Models) (L_F)

Enter the depth to the <u>bottom</u> of the floor in contact with the soil. The default value for slab-on-grade and basement construction is 15 cm and 200 cm, respectively.

6. *Depth Below Grade to Top of Contamination* (Soil Models Only) (L_T)

Enter the depth to the top of soil contamination. If the contamination begins at the soil surface, enter the depth below grade to the <u>bottom</u> of the enclosed space floor. The depth to the top of contamination must be greater than or equal to the depth to the bottom of the floor.
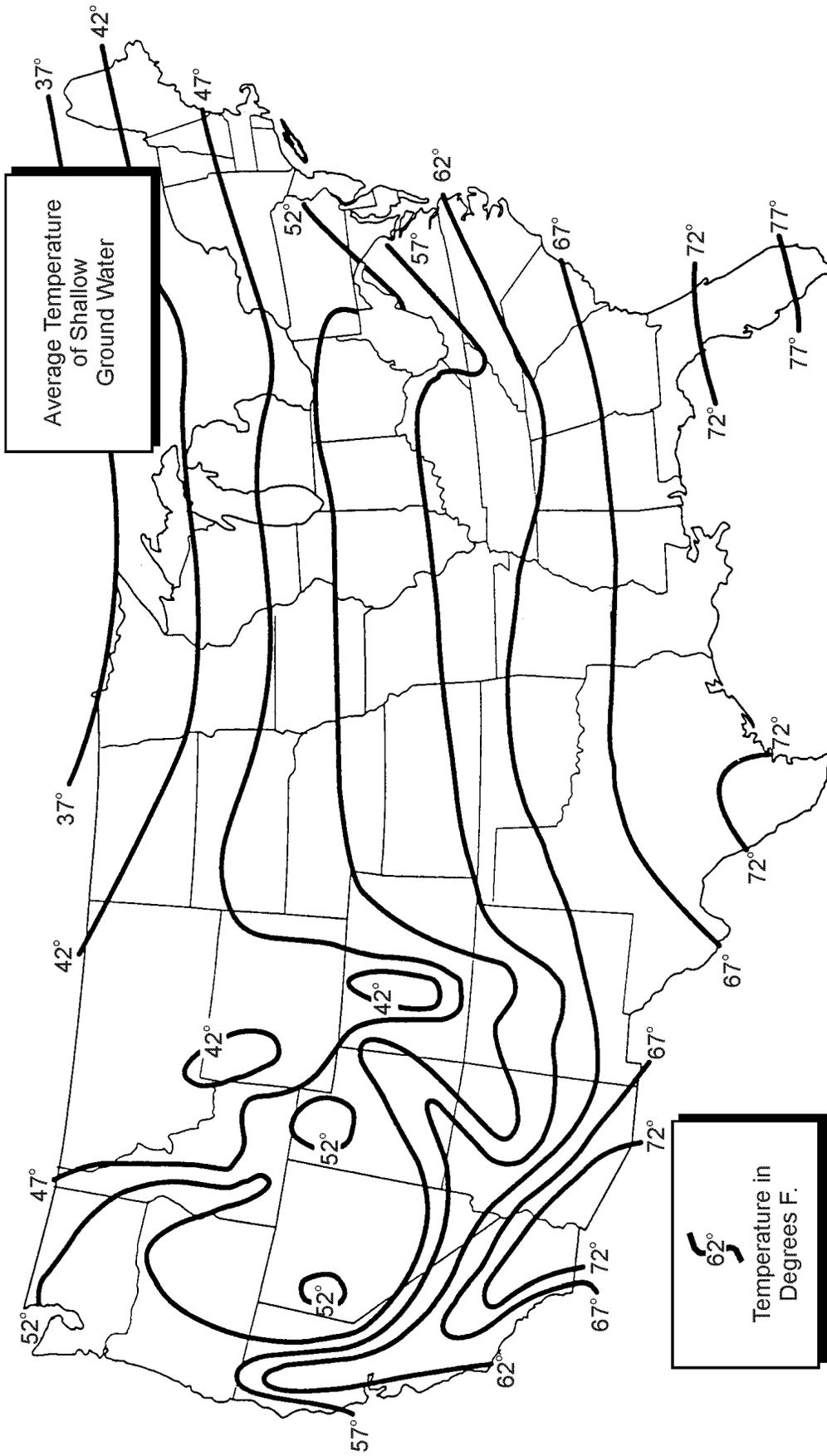
Figure 8. Average Shallow Groundwater Temperature in the United States

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7.	*Depth Below Grade to Water Table* (Groundwater Models Only) (L_{wt})

Enter the depth to the top of the water table (i.e., where the pressure head is equal to zero and the pressure is atmospheric).

Note:	The thickness of the capillary zone is calculated based on the SCS soil textural classification above the top of the water table. The depth below grade to the top of the water table minus the thickness of the capillary zone must be greater than the depth below grade to the bottom of the enclosed space floor. This means that the top of the capillary zone is always below the floor.

8.	*Depth Below Grade to Bottom of Contamination* (Advanced Soil Model Only) (L_B)

This value is used to calculate the thickness of soil contamination. A value greater than zero and greater than the depth to the top of contamination will automatically invoke the finite source model. If the thickness of contamination is unknown, two options are available:

1.	Entering a value of zero will automatically invoke the infinite source model.

2.	Enter the depth to the top of the water table. This will invoke the finite source model under the assumption that contamination extends from the top of contamination previously entered down to the top of the water table.

9.	*Thickness of Soil Stratum "X"* (Advanced Models Only) (h_x, x = A, B, or C)

In the advanced models, the user can define up to three soil strata between the soil surface and the top of contamination or to the soil gas sampling depth, as appropriate. These strata are listed as A, B, and C. Stratum A extends down from the soil surface, Stratum B is below Stratum A, and Stratum C is the deepest stratum. The thickness of Stratum A must be at least as thick as the depth below grade to the bottom of the enclosed space floor. The combined thickness of all strata must be equal to the depth to the top of contamination, or to the soil gas sampling depth, as appropriate. If soil strata B and/or C are not to be considered, a value of zero <u>must</u> be entered for each stratum not included in the analysis.

10.	*Soil Stratum A SCS Soil Type* (Advanced Models Only) (SES – soil)

Enter one of the following SCS soil type abbreviations:

Abbreviation	SCS Soil Type
C	Clay
CL	Clay loam
L	Loam
LS	Loamy sand
S	Sand
SC	Sandy clay
SCL	Sandy clay loam
SI	Silt
SIC	Silty clay
SICL	Silty clay loam
SIL	Silty loam
SL	Sandy loam

The SCS soil textural classification can be determined by using either the ATSM Standard Test Method for Particle-Size Analysis of Soils (D422-63) or by using the analytical procedures found in the U.S. Natural Resources Conservation Service (NRCS) Soil Survey Laboratory Methods Manual, Soil Survey Laboratory Investigations Report No. 42. After determining the particle size distribution of a soil sample, the SCS soil textural classification can be determined using the SCS classification chart in Figure 7.

The SCS soil type along with the Stratum A soil water-filled porosity is used to estimate the soil vapor permeability of Stratum A which is in contact with the floor and walls of the enclosed space below grade. Alternatively, the user may define a soil vapor permeability (see Variable No. 11).

11.   *User-Defined Stratum A Soil Vapor Permeability* (Advanced Models Only)(K_v)

As an alternative to estimating the soil vapor permeability of soil Stratum A, the user may define the soil vapor permeability. As a general guide, the following represent the practical range of vapor permeabilities:

Soil type	Soil vapor permeability, cm^2
Medium sand	1.0×10^{-7} to 1.0×10^{-6}
Fine sand	1.0×10^{-8} to 1.0×10^{-7}
Silty sand	1.0×10^{-9} to 1.0×10^{-8}
Clayey silts	1.0×10^{-10} to 1.0×10^{-9}

12.   *Vadose Zone SCS Soil Type* (Screening Models Only) (SCS – soil)

Because the screening-level models accommodate only one soil stratum above the top of contamination or soil gas sampling depth, enter the SCS soil type from the list given in Variable No. 10.

13.   *User-Defined Vadose Zone Soil Vapor Permeability* (Screening Models Only) (K_v)

For the same reason cited in No. 12 above, the user may alternatively define a soil vapor permeability. Use the list of values given in Variable No. 11 as a general guide.

14.   *Soil Stratum Directly Above the Water Table* (Advanced Groundwater Models Only) (A, B, or C)

Enter either A, B, or C as the soil stratum directly above the water table. This value must be the letter of the deepest stratum for which a thickness value has been specified under Variable No. 9.

15.   *SCS Soil Type Directly Above Water Table* (Groundwater Models Only) (SCS – soil)

Enter the correct SCS soil type from the list given in Variable No. 10 for the soil type directly above the water table. The soil type entered is used to estimate the rise (thickness) of the capillary zone.

16.   *Stratum "X" Soil Dry Bulk Density* (Advanced Models Only) (P_x, x = A, B, or C)

Identify the soil type for each strata and accept the default value or enter a site-specific value for the average soil dry bulk density. Dry bulk density is used in a number of intermediate calculations and is normally determined by field measurements (ASTM D 2937 Method).

17.   *Stratum "X" Soil Total Porosity* (Advanced Models Only) (n^x, x = A, B, or C)

Total soil porosity (n) is determined as:

$$n = 1\ \rho_b/\rho_s$$

where ρ_b is the soil dry bulk density (g/cm^3) and ρ_s is the soil particle density (usually 2.65 g/cm^3).

18.   *Stratum "X" Soil Water-Filled Porosity* (Advanced Models Only) (θ_w^x, X = a, b, or c)

Enter the average long-term volumetric soil moisture content; this is typically a depth-averaged value for the appropriate soil stratum. A long-term average value is typically not readily available. Do not use values based on episodic measurements unless they are representative of long-term conditions.

One option is to use a model to estimate the long-term average soil water-filled porosities of each soil stratum between the enclosed space floor and the top of contamination. The HYDRUS model version 5.0 (Vogel et al., 1996) is a public domain code for simulating one-dimensional water flow, solute transport, and heat movement in variably-saturated soils. The water flow simulation module of HYDRUS will generate soil water content as a function of depth and time given actual daily precipitation data. Model input requirements include either the soil hydraulic properties of van Genuchten (1980) or those of Brooks and Corey (1966). The van Genuchten soil hydraulic properties required are the same as those given in Tables 3 and 4 (i.e., θ_s, θ_r, N, α_1, and K_s). The HYDRUS model is available from the U.S. Department of Agriculture (USDA) - Agricultural Research Service in Riverside,   California   via   their   internet   website   at http://www.ussl.ars.usda.gov/MODELS/HYDRUS.HTM. One and two-dimensional commercial versions of HYDRUS (Windows versions) are available at the International   Ground   Water   Modeling   Center   website   at http://www.mines.edu/research/igwmc/software/.   Schaap and Leij (1998) have recently developed a Windows program entitled ROSETTA for estimating the van Genuchten soil hydraulic properties based on a limited or more extended set of input data.   The ROSETTA program can be found at the USDA website: http://www.ussl.ars.usda.gov/MODELS/rosetta/rosetta.htm.   The van Genuchten

hydraulic properties can then be input into HYDRUS to estimate soil moisture content.

19. *Stratum "X" Soil Organic Carbon Fraction* (Advanced Soil Models Only) (f_{oc}^X, X = A, B, or c)

   Enter the depth-averaged soil organic carbon fraction for the stratum specified. Soil organic carbon is measured by burning off soil carbon in a controlled-temperature oven. This parameter, along with the chemical's organic carbon partition coefficient (K_{oc}), is used to determine the soil-water partition coefficient (K_d).

20. *Vadose Zone Soil Dry Bulk Density* (Screening Models Only) (ρ^A)

   Because the screening-level models accommodate only one soil stratum above the top of contamination, identify the soil type and accept the default values or enter the depth-averaged soil dry bulk density. The universal default value is 1.5 g/cm^3, which is consistent with U.S. EPA (1996a and b) for subsurface soils.

21. *Vadose Zone Soil Total Porosity* (Screening Models Only) (m^A)

   Because the screening-level models accommodate only one soil stratum above the top of contamination, enter the depth-averaged soil total porosity. The default value is 0.43, which is consistent with U.S. EPA (1996a and b) for subsurface soils.

22. *Vadose Zone Soil Water-Filled Porosity* (Screening Models Only) (θ_w^A)

   Because the screening-level models accommodate only one soil stratum above the top of contamination, enter the depth-averaged soil water-filled porosity. The default value is 0.30, which is consistent with U.S. EPA (1996a and b) for subsurface soils.

23. *Vadose Zone Soil Organic Carbon Fraction* (Soil Screening Model Only) (f_{oc}^A)

   Because the screening-level models accommodate only one soil stratum above the top of contamination, enter the depth-averaged soil organic carbon fraction. The default value is 0.002, which is consistent with U.S. EPA (1996a and b) for subsurface soils.

24. *Enclosed Space Floor Thickness* (Advanced Models Only) (L_{crack})

   Enter the thickness of the floor slab. All models operate under the assumption that the floor in contact with the underlying soil is composed of impermeable concrete whether constructed as a basement floor or slab-on-grade. The default value is 10 cm, which is consistent with J&E (1991).

25. *Soil-Building Pressure Differential* (Advanced Models Only) (ΔP)

Because of wind effects on the structure, stack effects due to heating of the interior air, and unbalanced mechanical ventilation, a negative pressure with respect to the soil surface is generated within the structure. This pressure differential (ΔP) induces a flow of soil gas through the soil matrix and into the structure through cracks, gaps, and openings in the foundation. The effective range of values of ΔP is 0-20 pascals (Pa) (Loureiro et al., 1990; Eaton and Scott, 1984). Individual average values for wind effects and stack effects are approximately 2 Pa (Nazaroff et al., 1985; Put and Meijer, 1989). Typical values for the combined effects of wind pressures and heating are 4 to 5 Pa (Loureiro et al., 1990; Grimsrud et al., 1983). A conservative default value of ΔP was therefore chosen to be 4 Pa (40 g/cm-s^2).

For more information on estimating site-specific values of ΔP, the user is referred to Nazaroff et al. (1987) and Grimsrud et al. (1983).

26. *Enclosed Space Floor Length* (Advanced Models Only) (L_B)

The default value is 1000 cm (see Variable No. 28).

27. *Enclosed Space Floor Width* (Advanced Models Only) (W_B)

The default value is 1000 cm (see Variable No. 28).

28. *Enclosed Space Height* (Advanced Models Only) (H_B)

For a single story home, the variation in mixing height will be the greatest for houses with HVAC systems that result in significant air circulation (e.g., forced air heat pump). Mixing heights would be less for houses with electrical baseboard heaters. The mixing height is approximated by the room height. The default value is 2.44 meters for a single story house without a basement.

For a single story house with a basement less mixing would be expected because of the cross floor connections. The default values for a house with a basement is 3.66 m. This value represents a two-fold reduction in vapor concentrations between the floors.

29. *Floor-Wall Seam Crack Width* (Advanced Models Only) (W)

The conceptual model used in the spreadsheets follows that of Loureiro et al. (1990) and Nazaroff (1988) and is illustrated in Figure 9. The model is based on a single-family house with a poured concrete basement floor and wall foundations, or constructed slab-on-grade in similar fashion. A gap is assumed to exist at the
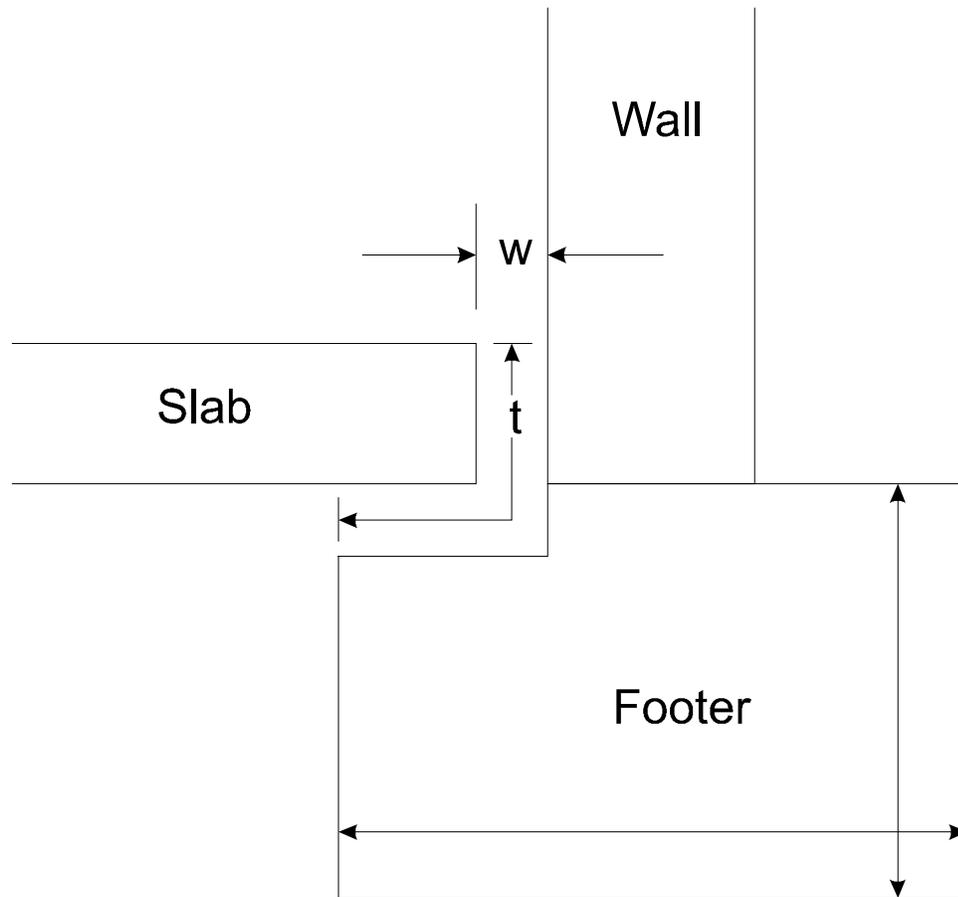
Figure 9. Floor Slab and Foundation

junction between the floor and the foundation along the perimeter of the floor. The gap exists as a result of building design or concrete shrinkage. This gap is assumed to be the only opening in the understructure of the house and therefore the only route for soil gas entry.

Eaton and Scott (1984) reported typical open areas of approximately 300 cm^2 for the joints between walls and floor slabs of residential structures in Canada. Therefore, given the default floor length and width of 1000 cm, a gap width (w) of 0.1 cm equates to a total gap area of 900 cm^2, which is reasonable given the findings of Eaton and Scott. This value of the gap width is also consistent with the typical value reported in Loureiro et al. (1990). The default value of the floor-wall seam crack width was therefore set equal to 0.1 cm.

30. *Indoor Air Exchange Rate* (Advanced Models Only) (ER)

The indoor air exchange rate is used along with the building dimensions to calculate the building ventilation rate. The default value of the indoor air exchange rate is 0.25/h. This value is consistent with the 10th percentile of houses in all regions of the U.S., as reported in Koontz and Rector (1995). This value is also consistent with the range of the control group of 331 houses in a study conducted by Parker et al. (1990) to compare data with that of 292 houses with energy-efficient features in the Pacific Northwest.

31. *Averaging Time for Carcinogens* (All Models) (AT_c)

Enter the averaging time in units of years. The default value is 70 years.

32. *Averaging Time for Noncarcinogens* (All Models) (AT_{nc})

Enter the averaging time in units of years. The averaging time for noncarcinogens is set equal to the exposure duration. The default value for residential exposure from U.S. EPA (1996a and b) is 30 years.

33. *Exposure Duration* (All Models) (ED)

Enter the exposure duration in units of years. The default value for residential exposure from U.S. EPA (1996a and b) is 30 years.

34. *Exposure Frequency* (All Models) (EF)

Enter the exposure frequency in units of days/yr. The default value for residential exposure from U.S. EPA (1996a and b) is 350 days/yr.

35. *Target Risk for Carcinogens* (All Soil and Groundwater Models) (TR)

If a risk-based media concentration is to be calculated, enter the target risk-level. The default value is 1×10^{-6}.

36. *Target Hazard quotient for Noncarcinogens* (All Soil and Groundwater Models) (THQ)

If a risk-based media concentration is to be calculated, enter the target hazard quotient. The default value is 1.

The remaining four worksheets include the results sheet (RESULTS) and three ancillary sheets. The ancillary sheets include the chemical properties sheet (CHEMPROPS), the intermediate calculations sheet (INTERCALCS), and the lookup tables (VLOOKUP).

3.5 THE RESULTS SHEET (RESULTS)

Once all data are entered in the data entry sheet, the model results may be viewed on the RESULTS sheet. For the soil and groundwater models, calculations are presented as either a risk-based soil or groundwater concentration, or the incremental risks associated with an initial soil or groundwater concentration. In the case of the advanced models, the user should check the message and error summary below the results section to ensure that no error messages appear. If one or more error messages appear, re-enter the appropriate data.

The RESULTS worksheet shows the indoor exposure soil or groundwater concentration for either a carcinogen or noncarcinogen as appropriate. When a contaminant is both a carcinogen and a noncarcinogen, the risk-based indoor exposure concentration is set equal to the lower of these two values. In addition, the soil saturation concentration (C_{sat}) or the aqueous solubility limit (S) is also displayed for the soil and groundwater models, respectively.

The equilibrium vapor concentration at the source of contamination is limited by the value of C_{sat} for soil contamination and by the value of S for groundwater contamination, as appropriate. For a single contaminant, the vapor concentration directly above the source of soil contamination cannot be greater than that associated with the soil saturation concentration; for groundwater contamination, the vapor concentration cannot be greater than that associated with the solubility limit. As a result, subsurface soil concentrations greater than C_{sat} and groundwater concentrations greater than S will not produce higher vapor concentrations. Therefore, if the indoor vapor concentration predicted from a soil concentration greater than or equal to the value of C_{sat} and it does not exceed the health-based limit in indoor air (target risk or target hazard quotient), the vapor intrusion pathway will not be of concern for that particular chemical. The same is true for an indoor vapor concentration predicted from a groundwater concentration greater than or equal to the value of S. That does not necessarily mean, however, that the subsurface contamination will not be of concern from a groundwater protection standpoint, (ingestion) and the potential for free-phase contamination (e.g., NAPL) must also be addressed.

For subsurface soils, the physical state of a contaminant at the soil temperature plays a significant role. When a contaminant is a liquid (or gas) at the soil temperature, the upper limit of the soil screening level is set at C_{sat}. This tends to reduce the potential for NAPL to exist within the vadose zone. The case is different for a subsurface contaminant that is a solid at the soil temperature. In this case, the screening level is not limited by C_{sat} because of the reduced possibility of leaching to the water table. If the model estimates a risk-based screening level greater than C_{sat} for a solid in soils, the model will display the final soil concentration as "NOC" or <u>N</u>ot <u>o</u>f <u>C</u>oncern for the vapor intrusion pathway.

In the case of groundwater contamination, the physical state of the contaminant is not an issue in that the contamination has already reached the water table. Because the equilibrium vapor concentration at the source of emissions cannot be higher than that associated with the solubility limit, the vapor concentration is calculated at the solubility limit if the user enters a groundwater concentration greater than the value of S when forward-calculating risk. When reverse-calculating a risk-based groundwater concentration, the model will display the final groundwater concentration as "NOC" for the vapor intrusion pathway if the model calculates a risk-based level greater than or equal to the value of S. It should be noted, however, that if the soil properties or other conditions specified in the DATENTER worksheet are changed, the final risk-based soil or groundwater concentration must be remodeled.

It should also be understood that if a contaminant is labeled "Not of Concern" for the vapor intrusion pathway, all other relevant exposure pathways must be considered for both contaminated soils and groundwater.

3.6   THE CHEMICAL PROPERTIES SHEET (CHEMPROPS)

The chemical properties sheet provides a summary of the chemical and toxicological properties of the chemical selected for analysis. These data are retrieved from the VLOOKUP sheet by CAS number. All data in the chemical properties sheet are protected.

3.7   THE INTERMEDIATE CALCULATIONS SHEET (INTERCALS)

The intermediate calculations sheet provides solutions to intermediate variables. Review of the values of the intermediate variables may be helpful in an analysis of the cause-and-effect relationships between input values and model results. All data in the intermediate calculations sheet are protected.

3.8   THE LOOKUP TABLES (VLOOKUP)

The VLOOKUP sheet contains two lookup tables from which individual data are retrieved for a number of model calculations. The first table is the Soil Properties Lookup Table. This table contains the average soil water retention curve data of Hers (2002) and Schaap and Leij (1998) and the mean grain diameter data of Nielson and Rogers (1990) by SCS soil type, and the mean dry bulk density from Leij, Stevens, et al (1994).

3.9   ADDING, DELETING, OR REVISING CHEMICALS

Data for any chemical may be edited, new chemicals added, or existing chemicals deleted from the Chemical Properties Lookup Table within the VLOOKUP worksheet. To begin an editing

session, the user must unprotect (unseal) the worksheet (the password is "ABC" in capital letters); editing of individual elements or addition and deletion of chemicals may then proceed. Space has been allocated for up to 260 chemicals in the lookup table. Row number 284 is the last row that may be used to add new chemicals. After the editing session is complete, the user must sort all the data in the lookup table (except the column headers) in ascending order by CAS number. After sorting is complete, the worksheet should again be protected (sealed).

SECTION 4

SOIL GAS MODEL APPLICATION

Two additional models have been added to allow the user to input measured soil gas concentration and sampling depth data directly into the spreadsheet. These models eliminate the need for theoretical partitioning of a total volume soil concentration or a groundwater concentration into discrete phases. This section provides instructions for using the soil gas models.

4.1   RUNNING THE MODELS

Two models are provided as MICROSOFT EXCEL spreadsheets. The screening-level model is titled SG-SCREEN.xls (EXCEL). The advanced model is titled SG-ADV.xls.

Both the screening-level and advanced models allow the user to calculate steady-state indoor air concentrations and incremental risks from user-defined soil gas concentration data. The models do not allow for reverse-calculation of a risk-based soil or groundwater concentration. As with the soil and groundwater screening-level models, the SG-SCREEN model operates under the assumption that the soil column properties are homogeneous and isotropic from the soil surface to an infinite depth. In addition, the SG-SCREEN model uses the same default values for the building properties as the SL-SCREEN and GW-SCREEN models. The advanced model allows the user to specify up to three different soil strata from the bottom of the building floor in contact with the soil to the soil gas sampling depth. Finally, the advanced model allows the user to specify values for all of the model variables.

To run the models, simply open the appropriate file within either MICROSOFT EXCEL worksheet. Each model is constructed of the following worksheets:

1.   DATENTER (Data Entry Sheet)
2.   CHEMPROPS (Chemical Properties Sheet)
3.   INTERCALCS (Intermediate Calculations Sheet)
4.   RESULTS (Results Sheet)
5.   VLOOKUP (Lookup Tables)

Each worksheet follows the form of the worksheets in the soil and groundwater models. See Section 4.2 for a description of each worksheet.

The DATENTER worksheet of each of the soil gas models is different than those of the soil and groundwater models. Figure 10 shows the DATA ENTER worksheet of the SG-ADV model. Note that there is no option for running the model to calculate a risk-based media concentration. As with the other models, the user enters the CAS number of the chemical of interest. This automatically retrieves the chemical and toxicological data for that chemical. The CAS number must match one of the chemicals listed in the VLOOKUP worksheet, or the message "CAS No. not found" will appear in the "Chemical" box. The user also has the opportunity to add new chemicals to the data base. Next, the user must enter a value for the soil gas concentration of the chemical of interest. The user may enter this value in units of $\mu g/m^3$ or parts-per-million by volume (ppmv). If the soil gas concentration is entered in units of ppmv, the concentration is converted to units of $\mu g/m^3$ by:

$$C_g' = \frac{C_g \times MW}{R \times T_S} \tag{33}$$

where C_g' = Soil gas concentration, $\mu g/m^3$

C_g = Soil gas concentration, ppmv

MW = Molecular weight, g/mol

R = Gas constant (= 8.205 E-05 atm-m^3/mol-^oK)

T_S = System (soil) temperature, ^oK.

In the soil gas models, the steady-state indoor air concentration is calculated by Equation 19 (i.e., $C_{building} = \alpha\ C_{source}$). The value of the vapor concentration at the source of emissions (C_{source}) is assigned the value of the user-defined soil gas concentration. The value of the steady-state attenuation coefficient (α) in Equation 19 is calculated by Equation 13. Because no evaluation has been made of the extent of the source of emissions, steady-state conditions (i.e., a non-diminishing source) must be assumed.

The SG-SCREEN model operates under the assumption of homogeneously distributed soil properties and isotropic conditions with respect to soil vapor permeability from the soil surface to an infinite depth. The SG-ADV model, on the other hand, allows the user to specify up to three different soil strata between the building floor in contact with the soil and the soil gas sampling depth. Soil properties within these three strata may be varied to allow for different diffusion resistances to vapor transport.

4.2   SOIL GAS SAMPLING

In order to use the soil gas models, soil gas concentrations must be measured at one or more depths below ground surface (bgs). The user is advised to take samples directly under building slabs

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Figure 10. SG-ADV Data Entry Worksheet

or basement floors when possible. This can be accomplished by drilling through the floor and sampling through the drilled hole. Alternatively, an angle-boring rig can be used to sample beneath the floor from outside the footprint of the building. When sampling directly beneath the floor is not possible, enough samples adjacent to the structure should be taken to adequately estimate an average concentration based on reasonable spatial and temporal scales.

Soil gas measurements can be made using several techniques; however, active whole-air sampling methods and active or passive sorbent sampling methods are usually employed. Typically, a whole-air sampling method is used whereby a non-reactive sampling probe is inserted into the soil to a prescribed depth. This can be accomplished manually using a "slam bar," or a percussion power drill, or the probe can be inserted into the ground using a device such as a Geoprobe.® The Geoprobe® device is attached to the rear of a specially customized vehicle. In the field, the rear of the vehicle is placed over the sample location and hydraulically raised on its base. The weight of the vehicle is then used to push the sampling probe into the soil. A built-in hammer mechanism allows the probe to be driven to predetermined depths up to 50 feet depending on the type of soil encountered. Soil gas samples can be withdrawn directly from the probe rods, or flexible tubing can be connected to the probe tips at depth for sample withdrawal.

Whole-air sampling is typically accomplished using an evacuated Summa or equivalent canister, or by evacuation to a Tedlar bag. Normal operation includes the use of an in-line flow controller and a sintered stainless steel filter to minimize particles becoming entrained in the sample atmosphere. For a 6-liter Summa canister, a normal sampling flow rate for a 24-hr integrated sample might be on the order of 1.5 ml/min; however, higher sampling rates can be used for grab samples. The sampling rate chosen, however, must not be so high as to allow for ambient air inleakage between the annulus of the probe and the surrounding soils. Depending on the target compounds, excessive air inleakage can dilute the sample (in some cases below the analytical detection limits).

One way to check for inleakage is to test an aliquot of the sample gas for either nitrogen or oxygen content before the sample is routed to the canister or Tedlar bag. To test for nitrogen in real- or near real-time requires a portable gas chromatograph/mass spectrometer (GC/MS). A portable oxygen meter, however, can be used to test for sample oxygen content in real-time with a typical accuracy of one-half of one percent. If air inleakage is detected by the presence of excessive nitrogen or oxygen, the seal around the sample probe at the soil surface as well as all sampling equipment connections and fittings should be checked. Finally, the flow rate may need to be reduced to decrease or eliminate the air inleakage.

The collection and concentration of soil gas contaminants can be greatly affected by the components of the sampling system. It is imperative to use materials that are inert to the contaminants of concern. Areas of sample collection that need particular attention are:

- The seal at the soil surface around the sample probe
- Use of a probe constructed of stainless steel or other inert material
- Minimization of the use of porous or synthetic materials (i.e., PTFE, rubber, or most plastics) that may adsorb soil gas and cause cross-contamination

- Purging of the sample probe and collection system before sampling
- Leak-check of sampling equipment to reduce air infiltration
- Keeping the length of all sample transfer lines as short as possible to minimize condensation of extracted gas in the lines.

The choice of analytical methods for whole-air soil gas sampling depends on the contaminants of concern. Concentrations of volatile organic compounds (VOCs) in the soil gas are typically determined using EPA Method TO-14 or TO-15. In the case of semi-volatile compounds, an active sorbent sampling methodology can be used. In this case, a low-volume sampling pump is normally used to withdraw the soil gas, which is then routed to a polyurethane foam (PUF) plug. Vapor concentrations of semi-volatile contaminants sorbed to the PUF are then determined using EPA Method TO-10. The active soil gas sampling equipment can be assembled to allow for both canister sampling for volatiles and PUF sampling for semi-volatiles.

Passive sorbent sampling involves burial of solid sorbent sampling devices called cartridges or cassettes to a depth of normally 5 feet or less. The cassettes may be configured with one or more sorbents depending on the list of target analytes, and are typically left in-ground for 72 to 120 hours or longer. During this time period, the vapor-phase soil gas contaminants pass through the cassette and are adsorbed as the soil gas moves toward the soil surface by diffusion and/or convection. Analytical methods for sorbent sampling depend on the target analytes and the sorbent used and may include EPA Method TO-10 or a modified EPA Method TO-1. Vapor-phase concentrations for some solid sorbent sampling systems are determined using the total mass of each contaminant recovered, the time in-ground, the cross-sectional area of the cassette, the diffusivity of the compound in air, and a quasi-empirical adsorption rate constant.

Recent EPA technology verification reports produced by the EPA National Exposure Research Laboratory (EPA 1998, 1998a) concluded, at least for two such systems, that the sorbent methodologies accurately accounted for the presence of most of the soil gas contaminants in the studies. Further, the reports concluded that the sorbent systems showed detection of contaminants at low concentrations not reported using an active whole-air sampling system. For one system, however, it was noted that as the vapor concentrations reported for the whole-air sampling system increased by 1 to 4 orders-of-magnitude, the associated concentrations reported for the sorbent system increased only marginally. Perhaps the best use of such passive sorbent sampling methods is to help confirm which contaminants are present in the soil gas and not necessarily contaminant concentrations.

An excellent discussion of soil gas measurement methods and limitations can be found in the ASTM Standard Guide for Soil Gas Monitoring in the Vadose Zone D5314-92e1. ASTM Standard Guides are available from the ASTM website at:

http://www.astm.org.

In addition, soil gas measurement method summaries can be found in the EPA Standard Operating Procedures for Soil Gas Sampling (SOP No. 2042) developed by the EPA Environmental Response

Team (ERT) in Edison, New Jersey. This document can be downloaded from the ERT Compendium of Standard Operating Procedures at the following website:

http://www.ert.org/media_resrcs/media_resrcs.asp.

Data Quality and Data Quality Objectives

The results of soil gas sampling must meet the applicable requirements for data quality and satisfy the data quality objectives of the study for which they are intended. Data quality objectives are qualitative and quantitative statements derived from the data quality objectives process that clarify study objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used to support site decisions. Data quality objectives are formulated in the first phase of a sampling project.

In the second phase of the project, a Quality Assurance Project Plan (QAPP) translates these requirements into measurement performance specifications and quality assurance/quality control procedures to provide the data necessary to satisfy the user's needs. The QAPP is the critical planning document for any environmental data collection operation because it documents how quality assurance and quality control activities will be implemented during the life of the project. Development of the data quality objectives and the QAPP for soil gas sampling should follow the guidance provided by EPA's Quality Assurance Division of the Office of Research and Development. Guidance documents concerning the development and integration of the data quality objectives and the QAPP can be obtained from the EPA website at:

http://epa.gov/ncerqa/qa/qa_docs.html.

In addition to the above guidance, the EPA Regional Office and/or other appropriate regulatory agency should be consulted concerning specific sampling requirements.

4.3   ASSUMPTIONS AND LIMITATIONS OF THE SOIL GAS MODEL

As discussed previously, the soil gas models operate under the assumption of steady-state conditions. This means that enough time has passed for the vapor plume to have reached the building of interest directly above the source of contamination and that the vapor concentrations have reached their maximum values. Depending on the depth at which the soil gas is sampled, diffusion of the soil gas toward the building is a function of the soil properties between the building floor in contact with the soil and the sampling depth. Convection of the soil gas into the structure is a function of the building properties and the effective soil vapor permeability. Assumptions and limitations of the soil gas models are the same as those in Section 2.11 with the exception of the source vapor concentration that is determined empirically through soil gas sampling.

The user should also recognize the inherent limitations of soil gas sampling. First, the geologic variability of the subsurface may be considerable. This may be especially problematic for

shallow soil gas sampling because soil moisture content can vary widely as a function of precipitation events and surface runoff. The soil moisture content has an exponential effect on the rate of vapor diffusion. Transformation processes such as biodegradation can also occur in shallow subsurface soils. In some cases, only a relatively thin stratum of bioactive soil can greatly reduce the emission flux toward the soil surface. Finally, subsurface phase equilibria is a dynamic process resulting in varying vapor-phase concentrations over time at the same sampling location and depth. These factors can result in significant differences in measured soil gas concentrations over relatively small spatial and temporal scales.

For these reasons, the planning phase of the soil gas-sampling program should carefully consider the inherent uncertainties in site-specific sampling and analytical data. In the final analysis, the extent of soil gas sampling is a trade-off between sampling costs and the degree of certainty required in the soil gas concentration data.

SECTION 5

ASSUMPTIONS AND LIMITATIONS OF THE J&E MODEL

The J&E Model is a one-dimensional analytical solution to diffusive and convective transport of vapors into indoor spaces. The model is formulated as an attenuation factor that relates the vapor concentration in the indoor space to the vapor concentration at the source. It was developed for use as a screening level model and consequently is based on a number of simplifying assumptions regarding contaminant distribution and occurrence, subsurface characteristics, transport mechanisms, and building construction.

EPA is suggesting that the J&E Model be used at Resource Conservation and Recovery Act (RCRA) Corrective Action Sites, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Sites, and voluntary cleanup sites. EPA is not recommending that the J&E Model be used for sites contaminated with petroleum products if the products were derived from Underground Storage Tanks. The J&E Model does not account for contaminant attenuation (biodegradation, hydrolysis, sorption, and oxidation/reduction). Attenuation is potentially a significant concern for these type of sites. EPA is recommending that investigators use OSWER Directive 9610.17: Use of Risk Based Decision-Making in UST Corrective Action Programs to evaluate these types of sites.

The J&E Model as implemented by EPA assumes homogeneous soil layers with isotropic properties that characterize the subsurface. The first tier spreadsheet versions allow only one layer; the advanced spreadsheet versions allow up to three layers. Sources of contaminants that can be modeled include dissolved, sorbed, or vapor sources where the concentrations are below the aqueous solubility limit, the soil saturation concentration, and/or the pure component vapor concentration. The contaminants are assumed to be homogeneously distributed at the source. All but one of the spreadsheets assumes an infinite source. The exception is the advanced model for a bulk soil source, which allows for a finite source. For the groundwater and bulk soil models, the vapor concentration at the source is calculated assuming equilibrium partitioning. Vapor from the source is assumed to diffuse directly upward (one-dimensional transport) through uncontaminated soil (including an uncontaminated capillary fringe if groundwater is the vapor source) to the base of a building foundation, where convection carries the vapor through cracks and openings in the foundation into the building. Both diffusive and convective transport processes are assumed to be at steady state. Neither sorption nor biodegradation is accounted for in the transport of vapor from the source to the base of the building.

The assumptions described above and in Table 12 suggest a number of conditions that preclude the use of the Non-NAPL Models as implemented by EPA. These conditions include:

TABLE 12. ASSUMPTIONS AND LIMITATIONS OF THE VAPOR INTRUSION MODEL

Assumption	Implication	Field Evaluation
Contaminant		
No contaminant free-liquid/precipitate phase present	J&E Model not representative of NAPL partitioning from source	NAPL or not at site–easier to evaluation for floating product or soil contamination sites. Most DNAPL sites with DNAPL below the water table defy easy characterization.
Contaminant is homogeneously distributed within the zone of contamination		
No contaminant sources or sinks in the building.	Indoor sources of contaminants and/or sorption of vapors on materials may confound interpretation of results.	Survey building for sources, assessment of sinks unlikely
Equilibrium partitioning at contaminant source.	Groundwater flow rates are low enough so that there are no mass transfer limitations at the source.	Not likely
Chemical or biological transformations are not significant (model will predict more intrusion)	Tendency to over predict vapor intrusion for degradable compounds	From literature
Subsurface Characteristics		
Soil is homogeneous within any horizontal plane	Stratigraphy can be described by horizontal layers (not tilted layers)	Observe pattern of layers and unconformities Note: In simplified J&E Model layering is not considered
All soil properties in any horizontal plane are homogeneous		
The top of the capillary fringe must be below the bottom of the building floor in contact with the soil.		
EPA version of JE Model assumes the capillary fringe is uncontaminated.		
Transport Mechanisms		
One-dimensional transport	Source is directly below building, stratigraphy does not influence flow direction, no effect of two- or three-dimensional flow patterns.	Observe location of source, observe stratigraphy, pipeline conduits, not likely to assess two- and three-dimensional pattern.
Two separate flow zones, one diffusive one convective.	No diffusion (dispersion) in the convective flow zone. Plug flow in convective zone	Not likely
Vapor-phase diffusion is the dominant mechanism for transporting contaminant vapors from contaminant sources located away from the foundation to the soil region near the foundation	Neglects atmospheric pressure variation effects, others?	Not likely

(continued)

Assumption	Implication	Field Evaluation
Straight-line gradient in diffusive flow zone.	Inaccuracy in flux estimate at match point between diffusive and convective sections of the model.	Not likely
Diffusion through soil moisture will be insignificant (except for compounds with very low Henry's Law Constant	Transport through air phase only. Good for volatiles. Only low volatility compounds would fail this and they are probably not the compounds of concern for vapor intrusion	From literature value of Henry's Law Constant.
Convective transport is likely to be most significant in the region very close to a basement, or a foundation, and vapor velocities decrease rapidly with increasing distance from a structure		Not likely
Vapor flow described by Darcy's law	Porous media flow assumption.	Observations of fractured rock, fractured clay, karst, macropores, preferential flow channels.
Steady State convection	Flow not affected by barometric pressure, infiltration, etc.	Not likely
Uniform convective flow near the foundation	Flow rate does not vary by location	Not likely
Uniform convective velocity through crack or porous medium	No variation within cracks and openings and constant pressure field between interior spaces and the soil surface	Not likely
Significant convective transport only occurs in the vapor phase	Movement of soil water not included in vapor impact	Not likely
All contaminant vapors originating from directly below the basement will enter the basement, unless the floor and walls are perfect vapor barriers. (Makes model over est. vapors as none can flow around the building)	Model does not allow vapors to flow around the structure and not enter the building	Not likely
Contaminant vapors enter structures primarily through cracks and openings in the walls and foundation	Flow through the wall and foundation material itself neglected	Observe numbers of cracks and openings. Assessment of contribution from construction materials themselves not likely

- The presence or suspected presence of residual or free-product non-aqueous phase liquids (LNAPL, DNAPL, fuels, solvents, etc.) in the subsurface.

- The presence of heterogeneous geologic materials (other than the three layers allowed in the advanced spreadsheets) between the vapor source and building. The J&E Model does not apply to geologic materials that are fractured, contain macropores or other preferential pathways, or are composed of karst.

- Sites where significant lateral flow of vapors occurs. These can include geologic layers that deflect contaminants from a strictly upward motion and buried pipelines or conduits that form preferential paths. Significantly different permeability contrasts between layers are likely to cause lateral flow of vapors. The model assumes the source of contaminants is directly below the potential receptors.

- Very shallow groundwater where the building foundation is wetted by the groundwater.

- Very small building air exchange rates (e.g., <0.25/h)

- Buildings with crawlspace structures or other significant openings to the subsurface (e.g., earthen floors, stone buildings, etc.). The EPA spreadsheet only allows for either slab on grade or basement construction.

- Contaminated groundwater sites with large fluctuations in the water table elevation. In these cases, the capillary fringe is likely to be contaminated; whereas in the groundwater source spreadsheets, the capillary fringe is assumed to be uncontaminated.

In theory the above limitations are readily conceptualized, but in practice the presence of these limiting conditions may be difficult to verify even when extensive site characterization data are available. Conditions that are particularly difficult to verify in the field include the presence of residual non-aqueous phase liquids (NAPLs) in the unsaturated zone and the presence and influence of macropores, fractures and other preferential pathways in the subsurface. Additionally, in the initial stages of evaluation, especially at the screening level, information about building construction and water table fluctuations may not be available. Even the conceptually simple assumptions (e.g., one-dimensional flow, lack of preferential pathways) may be difficult to assess when there are little site data available.

The vapor equilibrium models employed to estimate the vapor concentration at the source of soil contamination is applicable only if "low" concentrations of the compound(s) are sorbed to organic carbon in the soil, dissolved in soil moisture, and present as vapor within the air-filled soil pores (i.e., a three-phase system). The vapor equilibrium models do not account for a residual phase NAPLs. If residual phase contaminants are present in the soil column, the user is referred to either the NAPL-SCREEN or NAPL-ADV model (Appendix A), as appropriate.

In the case of contaminated groundwater, the vapor equilibrium model operates under the assumption that the contaminant is present at levels below the water solubility limit. If the user-defined soil concentration is greater than the soil saturation concentration (C_{sat}) or if the groundwater concentration is greater than the solubility limit (S), the equilibrium vapor concentration will be calculated at the value of C_{sat} or S as appropriate.

The user is also reminded that when estimating a risk-based soil concentration, the model will compare the calculated soil concentration with the soil saturation concentration above which a residual phase is likely to occur. The soil saturation concentration (C_{sat}) is calculated as in U.S. EPA (1996a and b). If the risk-based concentration is greater than the saturation concentration and the contaminant is a liquid or gas at the soil temperature, the final soil concentration will be set equal to the soil saturation concentration. This tends to eliminate the possibility of allowing a liquid residual phase to exist within the soil column, which may leach to the water table. If the risk-based soil concentration is greater than C_{sat} and the contaminant is a solid, the contaminant is not of concern for the vapor intrusion pathway.

Likewise, the groundwater models will compare the calculated risk-based groundwater concentration to the aqueous solubility limit of the compound. If the risk-based groundwater concentration is greater than the solubility limit, the contaminant is not of concern for the vapor intrusion pathway.

Finally, it should be recognized that the procedures used to estimate both the soil saturation concentration and the aqueous solubility limit do not consider the effects of multiple contaminants. The estimated values, therefore, may be artificially high such that a residual phase may actually exist at somewhat lower concentrations.

The procedures used to estimate the soil vapor permeability of the soil stratum in contact with the building floor and walls assume isotropic soils and steady-state soil moisture content. In addition, the calculations do not account for preferential vapor pathways due to soil fractures, vegetation root pathways, or the effects of a gravel layer below the floor slab or backfill. These items may act to increase the vapor permeability of in situ soils.

If in situ pneumatic tests are used to measure site vapor permeability, care must be taken to ensure adequate sampling to reduce the possibility of missing important soil structure effects due to anisotropy.

Single-point in situ pneumatic tests are typically conducted by measuring the pressure in a probe as a metered flow of air is passed through the probe and into the soil. Garbesi et al. (1996), however, demonstrated that soil vapor permeability increases with the sampling length scale. Using a dual-probe dynamic pressure sampling apparatus, Garbesi et al. (1996) demonstrated that the average soil vapor permeability typically increases up to a constant value as the distance between the source probe and detector probe increases. On a length scale typical of a house (3 to 10 m), use of the dual-probe sampling technique found that the soil permeability was approximately 10 to 20 times higher than that measured by the single-point method. Although arguably the most accurate means of determining in situ soil vapor permeability, the techniques of Garbesi et al. (1996) are complex and require specialized equipment.

Another method for determining the intrinsic permeability of soil is to conduct empirical measurements of the saturated hydraulic conductivity (K_s). These data are then input into Equation

26. The resulting value of k_i is then multiplied by the relative air permeability (k_{rg}) calculated by Equation 27 to yield the effective air permeability of the soil.

Estimation of the rise of the capillary zone is based on the equation for the rise of a liquid in a capillary tube. The procedure assumes that the interstitial space between the soil particles is equivalent to the capillary tube diameter and that the resulting rise of water occurs under steady-state soil column drainage conditions. In actuality, the height of the capillary zone is uneven or fingered due to the variation in the actual in situ particle size distribution. In addition, the groundwater models do not account for the episodic rise and fall of the water table or the capillary zone due to aquifer recharge and discharge. As constructed, the groundwater models do not allow the top of the capillary zone to be above the bottom of the building floor in contact with the soil. The user should be aware, however, that in reality the top of the capillary zone may rise to levels above the floor in some cases.

Diffusion across the capillary zone is estimated based on lumping vapor and aqueous-phase diffusion together within the calculation of the effective diffusion coefficient. To allow for vapor-phase diffusion within the capillary zone, the air-filled soil pores must be connected. In reality, the capillary zone may be comprised of a tension-saturated zone immediately above the water table and the deep portion of the vadose zone within which the soil water content is strongly dependent on the pressure head. Diffusion across the tension-saturated zone is dominated by liquid-phase diffusion, which is typically four orders of magnitude less than vapor-phase diffusion. Therefore, a large concentration gradient may exist between the top of the water table and the top of the tension-saturated zone (McCarthy and Johnson, 1993).

Lumping vapor and aqueous-phase diffusion together is a less-intensive, although less-rigorous, method for estimating the effective diffusion coefficient. The result is typically a higher effective diffusion coefficient relative to separate solutions for aqueous diffusion across the tension-saturated zone and both vapor and aqueous diffusion across the unsaturated portion of the vadose zone.

To minimize the possible overestimation of the effective diffusion coefficient, the soil air-filled porosity within the capillary zone is estimated based on the air-entry pressure head, which corresponds with the water-filled porosity at which the interstitial air-filled pores first become connected. The user should be aware that this procedure is inherently conservative if a significant concentration gradient exists across the tension-saturated zone. This conservatism may be somewhat offset in that the model does not consider any episodic rise in the level of the water table. During such events, water that had previously been part of the saturated zone (and hence contain higher contaminant concentrations) is redistributed in the vadose zone resulting in temporary elevations in soil gas concentrations.

The model assumes that all vapors from underlying soils will enter the building through gaps and openings in the walls, floor, and foundation. This implies that a constant pressure field is generated between the interior spaces and the soil surface and that the vapors are intercepted within the pressure field and transported into the building. This assumption is inherently conservative in

that it neglects periods of near zero pressure differentials (e.g., during mild weather when windows are left open).

As with the estimation procedure for soil vapor permeability, the model assumes isotropic soils in the horizontal direction; vertical anisotropy is accounted for by a series of isotropic soil strata above the top of contamination. Soil properties within the zone of soil contamination are assumed to be identical to those of the soil stratum directly above the contamination and extend downward to an infinite depth. Solute transports by convection (e.g., water infiltration) and by mechanical dispersion are neglected. Transformation processes (e.g., biodegradation, hydrolysis, etc.) are also neglected.

The J&E Model treats the entire building as a single chamber with instantaneous and homogeneous vapor dispersion. It therefore neglects contaminant sinks and the room-to-room variation in vapor concentration due to unbalanced mechanical and/or natural ventilation.

5.1   SOURCE VAPOR CONCENTRATION

As applied in the accompanying spreadsheets, the vapor equilibrium model employed to estimate the vapor concentration at the source of soil contamination is applicable in the limit of "low" concentrations where compounds are sorbed to organic carbon in the soil, dissolved is soil moisture, and present as vapor within the air-filled soil pores (i.e., a three-phase system). The model does not account for a residual phase (e.g., NAPL). If residual phase contaminants are present in the soil column, the user is referred to either the NAPL-SCREEN or NAPL-ADV model, as appropriate.

In the case of contaminated groundwater, the vapor equilibrium model operates under the assumption that the contaminant is present at levels below the water solubility limit. If the user-defined soil concentration is greater than the soil saturation concentration (C_{sat}) or if the groundwater concentration is greater than the solubility limit (S), the equilibrium vapor concentration will be calculated at the value of C_{sat} or S as appropriate.

The user is also reminded that when estimating a risk-based soil concentration, the model will compare the calculated soil concentration with the soil saturation concentration above which a residual phase is likely to occur. The soil saturation concentration (C_{sat}) is calculated as in U.S. EPA (1996a and b). If the risk-based concentration is greater than the saturation concentration and the contaminant is a liquid or gas at the soil temperature, the final soil concentration will be set equal to the soil saturation concentration. This tends to eliminate the possibility of allowing a liquid residual phase to exist within the soil column, which may leach to the water table. If the risk-based soil concentration is greater than C_{sat} and the contaminant is a solid, the contaminant is not of concern for the vapor intrusion pathway.

Likewise, the groundwater models will compare the calculated risk-based groundwater concentration to the aqueous solubility limit of the compound. If the risk-based groundwater

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concentration is greater than the solubility limit, the contaminant is not of concern for the vapor intrusion pathway.

Finally, it should be recognized that the procedures used to estimate both the soil saturation concentration and the aqueous solubility limit do not consider the effects of multiple contaminants. The estimated values, therefore, may be artificially high such that a residual phase may actually exist at somewhat lower concentrations.

5.2   SOIL VAPOR PERMEABILITY

The procedures used to estimate the soil vapor permeability of the soil stratum in contact with the building floor and walls assumes isotropic soils and steady-state soil moisture content. In addition, the calculations do not account for preferential vapor pathways due to soil fractures, vegetation root pathways, or the effects of a gravel layer below the floor slab or backfill which may act to increase the vapor permeability with respect to in situ soils.

If in situ pneumatic tests are used to measure site vapor permeability, care must be taken to ensure adequate sampling to reduce the possibility of missing important soil structure effects due to anisotropy.

Single point in situ pneumatic tests are typically conducted by measuring the pressure in a probe as a metered flow of air is passed through the probe and into the soil. Garbesi et al. (1996), however, demonstrated that soil vapor permeability increases with the sampling length scale. Using a dual-probe dynamic pressure sampling apparatus, Garbesi et al. (1996) demonstrated that the average soil vapor permeability typically increases up to a constant value as the distance between the source probe and detector probe increases. On a length scale typical of a house (3 to 10 m) use of the dual-probe sampling technique found that the soil permeability was approximately 10 to 20 times higher than that measured by the single point method. Although arguably the most accurate means of determining in situ soil vapor permeability, the techniques of Garbesi et al. (1996) are complex and require specialized equipment.

Another method for determining the intrinsic permeability of soil is to conduct empirical measurements of the saturated hydraulic conductivity (K_s). These data are then input into Equation 26. The resulting value of k_i is then multiplied by the relative air permeability (k_{rg}) calculated by Equation 27 to yield the effective air permeability of the soil.

5.3   RISE OF AND DIFFUSION ACROSS THE CAPILLARY ZONE

Estimation of the rise of the capillary zone is based on the equation for the rise of a liquid in a capillary tube. The procedure assumes that the interstitial space between the soil particles is equivalent to the capillary tube diameter and that the resulting rise of water occurs under steady-state soil column drainage conditions. In actuality, the height of the capillary zone is uneven or fingered due to the variation in the actual in situ particle size distribution. In addition, the groundwater

models do not account for the episodic rise and fall of the water table or the capillary zone due to aquifer recharge and discharge. As constructed, the groundwater models do not allow the top of the capillary zone to be above the bottom of the building floor in contact with the soil. The user should be aware, however, that in reality the top of the capillary zone might rise to levels above the floor in some cases.

Diffusion across the capillary zone is estimated based on lumping vapor and aqueous-phase diffusion together within the calculation of the effective diffusion coefficient. To allow for vapor-phase diffusion within the capillary zone, the air-filled soil pores must be connected. In reality, the capillary zone may be comprised of a tension-saturated zone immediately above the water table and the deep portion of the vadose zone within which the soil water content is a strongly dependent on the pressure head. Diffusion across the tension-saturated zone is dominated by liquid-phase diffusion which is typically four orders of magnitude less than vapor-phase diffusion. Therefore, a large concentration gradient may exist between the top of the water table and the top of the tension-saturated zone (McCarthy and Johnson, 1993).

Lumping vapor and aqueous-phase diffusion together is a less intensive, although less rigorous, method for estimating the effective diffusion coefficient. The result is typically a higher effective diffusion coefficient relative to separate solutions for aqueous diffusion across the tension-saturated zone and both vapor and aqueous diffusion across the unsaturated portion of the vadose zone.

To minimize the possible over estimation of the effective diffusion coefficient, the soil air-filled porosity within the capillary zone is estimated based on the air-entry pressure head, which corresponds with the water-filled porosity at which the interstitial air-filled pores first become connected. The user should be aware that this procedure is inherently conservative if a significant concentration gradient exists across the tension-saturated zone. This conservatism may be somewhat offset in that the model does not consider any episodic rise in the level of the water table. During such events, water which had previously been part of the saturated zone (and hence contain higher contaminant concentrations) is redistributed in the vadose zone resulting in temporary elevations in soil gas concentrations.

5.4   DIFFUSIVE AND CONVECTIVE TRANSPORT INTO THE STRUCTURE

The following is a discussion of the major assumptions and limitations of the J&E Model for diffusive and convective vapor transport into buildings.

The model assumes that all vapors from underlying soils will enter the building through gaps and openings in the walls, floor, and foundation. This implies that a constant pressure field is generated between the interior spaces and the soil surface and that the vapors are intercepted within the pressure field and transported into the building. This assumption is inherently conservative in that it neglects periods of near zero pressure differentials (e.g., during mild weather when windows are left open).

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As with the estimation procedure for soil vapor permeability, the model assumes isotropic soils in the horizontal direction; vertical anisotropy is accounted for by a series of isotropic soil strata above the top of contamination. Soil properties within the zone of soil contamination are assumed to be identical to those of the soil stratum directly above the contamination and extend downward to an infinite depth. Solute transports by convection (e.g., water infiltration) and by mechanical dispersion are neglected. Transformation processes (e.g., biodegradation, hydrolysis, etc.) are also neglected.

An empirical field study (Fitzpatrick and Fitzgerald, 1997) indicated that the model may be overly conservative for nonchlorinated species (e.g., benzene, toluene, ethylbenzene and xylene) but in some cases, may underpredict indoor concentrations for chlorinated species. The authors contribute the likely cause for this discrepancy to the significant biodegradation of the nonchlorinated compounds.

The J&E Model treats the entire building as a single chamber with instantaneous and homogeneous vapor dispersion. It therefore neglects contaminant sinks and the room-to-room variation in vapor concentration due to unbalanced mechanical and/or natural ventilation.

Finally, convective vapor flow from the soil matrix into the building is represented as an idealized cylinder buried below grade. This cylinder represents the total area of the structure below the soil surface (walls and floor). The total crack or gap area is assumed to be a fixed fraction of this area. Because of the presence of basement walls, the actual vapor entry rate is expected to be 50 to 100 percent of that provided by the idealized geometry (Johnson and Ettinger, 1991).

SECTION 6

INTERPRETATION OF RESULTS

The models described herein are theoretical approximations of complex physical and chemical processes and as such should not be used in a deterministic fashion (i.e., to generate a single outcome). At the least, a range of outcomes should be explored focusing on the most sensitive model input variables. In general, using the default values for input variables will result in higher indoor air concentrations and thus higher incremental risks or lower risk-based media concentrations. With a realistic range of outcomes, the risk manager may assess the uncertainty in the model predictions.

From a conceptual point of view, the vapor intrusion model provides a theoretical description of the processes involved in vapor intrusion from subsurface soils or groundwater into indoor structures. A combination of modeling and sampling methods is also possible to reduce the uncertainty of the calculated indoor air concentrations. Typically this involves field methods for measuring soil gas very near or below an actual structure. It should be understood, however, that soil gas sampling results outside the footprint of the building may or may not be representative of the soil gas concentrations directly below the structure. For solid building floors in contact with the soil (e.g., concrete slabs), the soil gas directly beneath the floor may be considerably higher than that adjacent to the structure. This is typically due to a vapor pooling effect underneath the near impermeable floor. Once a representative average concentration is determined, all vapor directly below the areal extent of the building is presumed to enter the structure. The soil gas concentration, along with the building ventilation rate and the soil gas flow rate into the building, will determine the indoor concentration. When using the soil gas models, it must be remembered that no analysis has been made concerning the source of contamination. Therefore, the calculated indoor concentration is assumed to be steady-state. The procedures described in API (1998) can be used to calibrate the diffusion transport considerations of the J&E Model as well as for calibrating the Model for transformation processes (e.g., biodegradation). The reader is also referred to U.S. EPA (1992) for a more detailed discussion of applying soil gas measurements to indoor vapor intrusion.

Finally, calibration and verification of the model have been limited due to the paucity of suitable data. Research is needed to provide spatially and temporally correlated measurements during different seasons, at different locations, with different buildings, and over a range of different contaminants such that the accuracy of the model may be determined. Appendix E contains bibliography and references.

APPENDIX A

USER'S GUIDE FOR NON-AQUEOUS PHASE LIQUIDS

Purpose

The NAPL-SCREEN and NAPL-ADV models are designed to forward calculate incremental cancer risks or noncarcinogenic hazard quotients due to subsurface soil vapor intrusion into buildings. The models are specifically designed to handle nonaqueous phase liquids or solids in soils. The user may specify up to 10 soil contaminants, the concentrations of which form a residual phase mixture. A residual phase mixture occurs when the sorbed phase, aqueous phase, and vapor phase of each chemical have reached saturation in soil. Concentrations above this saturation limit for all of the specified chemicals of a mixture will result in a fourth or residual phase (i.e., nonaqueous phase liquid or solid).

Other vapor intrusion models (SL-SCREEN, SL-ADV, SG-SCREEN, SG-ADV, GW-SCREEN, and GW-ADV) handled only a single contaminant and only when the soil concentration was at or below the soil saturation limit (i.e., a three-phase system). Use of these models when a residual phase is present, results in an overprediction of the soil vapor concentration and subsequently the building vapor concentration.

Residual Phase Theory

The three-phase system models estimate the equilibrium soil vapor concentration at the emission source (C_{source}) using the procedures from Johnson et al. (1990):

$$C_{source} = \frac{H'_{TS} C_R \rho_b}{\theta_w + K_d \rho_b + H'_{TS} \theta_a} \qquad (1)$$

where:

C_{source}	=	Vapor concentration at the source of contamination, g/cm^3
H'_{TS}	=	Henry's law constant at the soil temperature, dimensionless
C_R	=	Initial soil concentration, g/g
ρ_b	=	Soil dry bulk density, g/cm^3
θ_w	=	Soil water-filled porosity, cm^3/cm^3
K_d	=	Soil-water partition coefficient, cm^3/g ($= K_{oc} \times f_{oc}$)
θ_a	=	Soil air-filled porosity, cm^3/cm^3
K_{oc}	=	Soil organic carbon partition coefficient, cm^3/g
f_{oc}	=	Soil organic carbon weight fraction.

In Equation 1, the equilibrium vapor concentration is proportional to the soil concentration up to the soil saturation limit. When a residual phase is present, however, the vapor concentration is independent of the soil concentration but proportional to the mole fraction of the individual component of the residual phase mixture. In this case, the equilibrium vapor concentration must be calculated numerically for a series of time-steps. For each time-step, the mass of each constituent that is volatilized is calculated using Raoult's law and the appropriate mole fraction. At the end of each time-step, the total mass lost is subtracted from the initial mass and the mole fractions are recomputed for the next time-step.

The NAPL-SCREEN and NAPL-ADV models use the procedures of Johnson et al. (2001) to calculate the equilibrium vapor concentration at the source of emissions for each time-step. Within each model, the user-defined initial soil concentration of each component in the mixture is checked to see if a residual phase is present. This is done by calculating the product of the activity coefficient of component i in water (α_i) and the mole fraction of i dissolved in soil moisture (y_i) such that:

$$\alpha_i y_i = \frac{M_i}{\left[\left(P_i^v(T_S)\theta_a V / RT_S\right) + \left(M^{H2O}/\alpha_i\right) + \left(K_{d,i}M_{soil}/\alpha_i MW_{H2O}\right)\delta\left(M^{H2O}\right)\right]} \quad (2)$$

where:

M_i	=	Initial moles of component i in soil, moles	
$P_i^v(T_S)$	=	Vapor pressure of i at the average soil temperature, atm	
θ_a	=	Soil air-filled porosity, cm^3/cm^3	
V	=	Volume of contaminated soil, cm^3	
R	=	Ideal gas constant, 82.05 atm-cm^3/mol-$^\circ$K	
T_S	=	Average soil temperature, $^\circ$K	
M^{H_2O}	=	Total moles in soil moisture dissolved phase, moles	
α_i	=	Activity coefficient of i in water, unitless	
$K_{d,i}$	=	Soil-water partition coefficient of i, cm^3/g	
M_{soil}	=	Total mass of contaminated soil, g	
MW_{H2O}	=	Molecular weight of water, 18 g/mol	
$\delta(M^{H_2O})$	=	1 if $M^{H_2O} > 0$, and	
$\delta(M^{H_2O})$	=	0 if $M^{H_2O} = 0$.	

If the sum of all the values of $\alpha_i y_i$ for all of the components of the mixture is less than 1, the mixture does not contain a residual phase and the models are not applicable. In such cases, the SL-SCREEN or SL-ADV model can be used to estimate the building concentration.

Once it has been determined that a residual phase does exists, the mole fraction of each component (x_i) is determined by iteratively solving Equations 3 and 4 subject to the constraint that the sum of all the mole fractions equals unity ($\Sigma x_i = 1$):

$$x_i = \frac{M_i}{\left[\left(P_i^v(T_S)\theta_a V / RT_S\right) + M^{HC} + \left(M^{H2O}/\alpha_i\right) + \left(K_{d,i}M_{soil}/\alpha_i MW_{H2O}\right)\delta\left(M^{H2O}\right)\right]} \quad (3)$$

and,

$$x_i = \frac{M_i^{HC}}{M^{HC}} \quad (4)$$

where M_i^{HC} is the number of moles of component i in residual phase and M^{HC} is the total number of moles of all components in residual phase. The solution is simplified by assuming that M^{H_2O} is approximately equal to the number of moles of water in the soil moisture. With the mole fraction of each component at the initial time-step, the equilibrium vapor concentration at the source of emissions is calculated by Raoult's law:

$$C_{source} = \frac{x_i P_i^v(T_S)MW_i}{RT_S} \qquad (5)$$

where MW_i is the molecular weight of component i (g/mol).

At the beginning of each succeeding time-step, the number of moles of each chemical remaining in the soil from the previous time-step are again checked to see if a residual phase is present using Equation 2. When a residual phase is no longer present, the equilibrium vapor concentration at the source of emissions is calculated by:

$$C_{source} = \frac{\alpha_i y_i P_i^v(T_S)MW_i}{RT_S}. \qquad (6)$$

Ancillary Calculations

The activity coefficient of component i in water (α_i) is estimated from its solubility. Because hydrocarbons are typically sparingly soluble in water, the following generalization has been applied to compounds that are liquid or solid at the average soil temperature:

$$\alpha_i = (1/y_i) = (55.55 \text{ moles/L})MW_i / S_i \qquad (7)$$

where S_i is the solubility of component i (g/L). For gases at the average soil temperature, the corresponding relationship is:

$$\alpha_i = (1/y_i)\left(1atm / P_i^v(T_S)\right) = (55.55 \text{ moles} / L)\left(MW_i(1\ atm) / S_i P_i^v(T_S)\right). \qquad (8)$$

Assuming that the vapor behaves as an ideal gas with a relatively constant enthalpy of vaporization between 70°F and the average soil temperature, the Claussius-Clapeyron equation can be used to estimate the vapor pressure at the desired temperature:

$$P^v(T_S) = P^v(T_R) \times \exp\left[\left(\frac{T_B \times T_R}{(T_B - T_R)}\right)\left(\frac{1}{T_S} - \frac{1}{T_R}\right)\ln\left(\frac{P^v(T_R)}{P_B}\right)\right] \qquad (9)$$

where: $P^v(T_S)$ =   Vapor pressure at the desired temperature T_S, atm
          $P^v(T_R)$ =   Vapor pressure at the reference temperature T_R, atm

$$
\begin{array}{llll}
T_B & = & \text{Normal boiling point, } ^{\circ}\text{K} \\
T_R & = & \text{Vapor pressure reference temperature, } ^{\circ}\text{K} \\
T_S & = & \text{The desired temperature, } ^{\circ}\text{K} \\
P_B & = & \text{Normal boiling point pressure} = 1 \text{ atm.}
\end{array}
$$

Building Concentration

The vapor concentration within the building or enclosed space ($C_{building}$) is calculated using the steady-state solution of Johnson and Ettinger (1991) such that:

$$
C_{building} = \alpha C_{source}. \qquad (10)
$$

The steady-state attenuation coefficient (α) is calculated by:

$$
\alpha = \frac{\left[\left(\dfrac{D_T^{\,eff} A_B}{Q_{building} L_T}\right) \times \exp\left(\dfrac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right)\right]}{\left[\exp\left(\dfrac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) + \left(\dfrac{D_T^{\,eff} A_B}{Q_{building} L_T}\right) + \left(\dfrac{D_T^{\,eff} A_B}{Q_{soil} L_T}\right)\left[\exp\left(\dfrac{Q_{soil} L_{crack}}{D^{crack} A_{crack}}\right) - 1\right]\right]} \qquad (11)
$$

where:

$$
\begin{array}{lll}
\alpha & = & \text{Steady-state attenuation coefficient, unitless} \\
D_T^{\,eff} & = & \text{Total overall effective diffusion coefficient, cm}^2\text{/s} \\
A_B & = & \text{Area of the enclosed space below grade, cm}^2 \\
Q_{building} & = & \text{Building ventilation rate, cm}^3\text{/s} \\
L_T & = & \text{Source-building separation, cm} \\
Q_{soil} & = & \text{Volumetric flow rate of soil gas into the} \\
& & \text{enclosed space, cm}^3\text{/s} \\
L_{crack} & = & \text{Enclosed space foundation or slab thickness, cm} \\
A_{crack} & = & \text{Area of total cracks, cm}^2 \\
D^{crack} & = & \text{Effective diffusion coefficient through the cracks, cm}^2\text{/s.}
\end{array}
$$

The reader is referred to Section 2.5 of this Guidance for a more detailed discussion of the derivation of Equation 11 and procedures for determining values for model input parameters. Except for the calculation of the equilibrium vapor concentration at the source of emissions, NAPL-SCREEN is identical to the three-phase model SL-SCREEN and NAPL-ADV is identical to the three-phase model SL-ADV.

The NAPL-SCREEN and NAPL-ADV models explicitly solve for the time-averaged building concentration over the exposure duration using a forward finite-difference numerical approach. For each time-step δt:

$$
M_i(t + \delta t) = M_i(t) - \delta t \left(C_{building} \times Q_{building} / MW_i\right) \qquad (12)
$$

where $M_i(t)$ is the number of moles of component i in soil at the previous time and $M_i(t+\delta t)$ is the number of moles at the new time. The time-step interval is variable as a function of the percent of mass lost over the time-step. The user may specify a minimum and maximum percent loss allowed; these values are applied to the single component of the residual phase mixture with the highest mass loss rate during each time-step interval. If the user-specified maximum percent loss is exceeded, the next time-step interval is reduced by half; likewise, if the user-specified minimum percent loss is not achieved, the next time-step interval is increased by a factor of two. The instantaneous building concentration at time = t is calculated using Equation 10 for each time-step. The time-averaged building concentration is estimated using a trapezoidal approximation of the integral.

Model Assumptions and Limitations

The NAPL-SCREEN and NAPL-ADV models operate under the assumption that sufficient time has elapsed since the time of initial soil contamination for steady-state conditions to have been achieved. This means that the subsurface vapor plume has reached the bottom of the enclosed space floor and that the vapor concentration has reached its maximum value. An estimate of the time required to reach near steady-state conditions (τ_{ss}) can be made using the following equations from API (1998):

$$\tau_{ss} \cong \frac{R_v \theta_a L_T^{\;2}}{D^{eff}} \qquad (13)$$

and,

$$R_v = 1 + \frac{\theta_w}{\theta_a H'_{TS}} + \frac{\rho_b K_d}{\theta_a H'_{TS}} \qquad (14)$$

and,

$$D^{eff} = D_a \frac{\theta_a^{\;10/3}}{n^2} + \left(\frac{D_w}{H'_{TS}}\right) \frac{\theta_w^{\;10/3}}{n^2} \qquad (15)$$

where R_v is the unitless vapor phase retardation factor, L_T is the source-building separation (cm), D^{eff} is the effective diffusion coefficient (cm^2/s), D_a is the diffusivity in air (cm^2/s), D_w is the diffusivity in water (cm^2/s), and n is the soil total porosity (cm^3/cm^3). The NAPL-SCREEN and NAPL-ADV models are applicable only when the elapsed time since initial soil contamination meets or exceeds the value of τ_{ss} (see **Using the Models**).

Emission source depletion is calculated by estimating the rate of vapor loss as a function of time such that the mass lost at each time-step is subtracted from a finite mass of contamination at the source. This requires the model user to estimate the dimensions of the emission source, e.g., the length, width, and thickness of the contaminated zone. The model should only be used, therefore,

when the extent of soil contamination has been sufficiently determined. It should be noted that because the NAPL-SCREEN and NAPL-ADV models are one-dimensional, the areal extent of soil contamination (i.e., length × width) can be less than but not greater than the areal extent of the building floor in contact with the soil.

Each model treats the contaminated zone directly below the building as a box containing a finite mass of each specified compound. The initial contamination contained within the box is assumed to be homogeneously distributed. After each time-step, the remaining contamination is assumed to be instantaneously redistributed within the box to homogeneous conditions. The diffusion path length from the top of contamination to the bottom of the enclosed space floor therefore remains constant with time. Use of this simplifying assumption means that the degree of NAPL soil saturation is not required in the calculation of the total overall effective diffusion coefficient (D_T^{eff}).

As time proceeds, the concentration of the mixture of compounds within the soil column may reach the soil saturation limit. Below this point, a residual phase will cease to exist and the vapor concentration of each chemical will decrease proportional to its total volume soil concentration. Theoretically, the vapor concentration will decrease asymptotically, approaching but never reaching zero. Because of the nature of the numerical solution to equilibrium vapor concentration, however, compounds with high effective diffusion coefficients (e.g., vinyl chloride) may reach zero soil concentrations while other less volatile contaminants will not. If the initial soil concentrations are significantly higher than their respective values of the soil saturation concentration, a residual phase may persist up to the user-defined exposure duration.

Model assumptions and limitations concerning vapor transport and vapor intrusion into buildings are those specified for the three-phase models.

Using the Models

Each model is constructed as a Microsoft® Excel workbook containing five worksheets. The DATENTER worksheet is the data entry worksheet and also provides model results. The VLOOKUP worksheet contains the "Chemical Properties Lookup Table" with listed chemicals and associated chemical and toxicological properties. It should be noted that the toxicological properties for many of these chemicals were derived by route-to-route extrapolation. In addition, the VLOOKUP worksheet includes the "Soil Properties Lookup Table" containing values for model intermediate variables used in estimating the soil vapor permeability. The CHEMPROPS worksheet provides a summary of the chemical and toxicological properties of the soil contaminants selected by the user. In addition, the CHEMPROPS worksheet provides calculated values for the soil saturation concentration (C_{sat}) and the time to reach steady-state conditions (τ_{ss}) once all required data are entered into the DATENTER worksheet. The INTERCALCS worksheet contains calculated values of intermediate model variables. Finally, the COMPUTE worksheet contains the numerical solutions for equilibrium vapor concentration and building vapor concentration as a function of time.

Both models use the Microsoft® SOLVER add-in algorithms to simultaneously solve Equations 3 and 4 for each of up to 10 chemicals specified by the user. In order to run NAPL-SCREEN or NAPL-ADV, the SOLVER add-in <u>must</u> be loaded into EXCEL. The user is referred to the EXCEL instructions for loading the SOLVER add-in.

On the DATENTER worksheet, the user may specify up to 10 soil contaminants by CAS number along with associated soil concentrations in units of mg/kg. The CAS number entered must match exactly one of the 93 chemicals listed in the VLOOKUP worksheet or the error message "CAS No. not found" will appear in the "Chemical" box. If the list of chemicals and concentrations entered does not constitute a residual phase, the error message in Figure 1 will appear after starting the model.

Figure 1. Residual Phase Error Message

Model Not Applicable!

⊗ The mixture of compounds and concentrations listed does not include a residual phase.
This model is not applicable!

OK
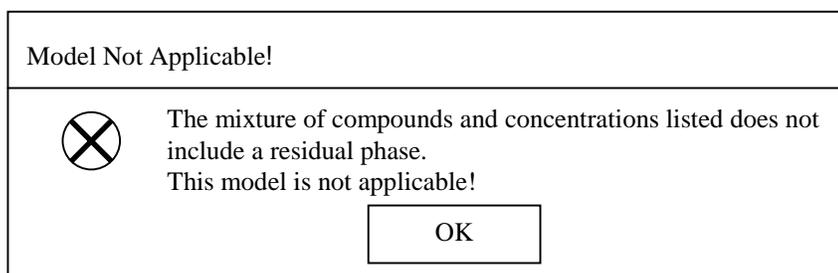
If this error message box appears, use either the SL-SCREEN or SL-ADV model to estimate subsurface vapor intrusion into the building.

After starting the model calculations, other error message boxes may appear if data entry values are missing on the DATENTER worksheet or if entered values do not conform to model assumptions. If such an error message box appears, fill-in missing data or re-enter data as appropriate. If entered data values are outside the expected range or if text values are entered where numeric values are expected, the model calculation macro will be suspended and the run-time error message in Figure 2 will appear.

Figure 2. Run-Time Error Message

Microsoft Visual Basic

Run-time error '13'
Type mismatch

Continue   End   Debug   Help
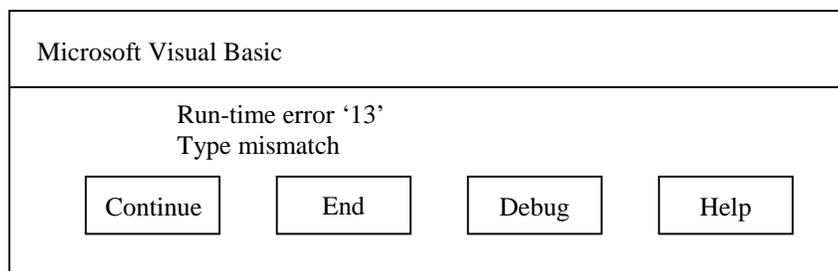
Should this error message appear, click on the "End" button to terminate the macro and return to the DATENTER worksheet. At this point, the user should review all of the entered values and make the appropriate corrections.

In addition to contaminant data, soil properties data, zone of contamination data, and exposure assumptions must also be specified in the DATENTER worksheet. Similar to the SL-SCREEN three-phase model, the NAPL-SCREEN model allows for only one soil stratum between the top of contamination and the bottom of the building floor in contact with the soil. In addition, the NAPL-SCREEN model uses built-in default values for all building variables (e.g., building dimensions, air exchange rate, total crack area, etc.). These default values are for single-family detached residences; therefore, the NAPL-SCREEN model should only be used for the residential exposure scenario.

The NAPL-ADV model, like the SL-ADV model, allows for up to three different soil strata between the top of contamination and the bottom of the building floor. In addition, the NAPL-ADV model allows the user to enter values for all model variables. This allows for the estimation of soil vapor intrusion into buildings other than single-family residences.

For each model, the user must also enter the duration of the first (initial) time-step interval. The maximum and minimum change in mass for each time-step must also be specified. The values of the initial time-step interval, and the maximum and minimum change in mass are important. If these values are too low, the model will calculate very small increments in the mass lost over time which will greatly extend the run-time of the model. In general, if the concentrations of the least volatile chemicals in the mixture are well above their respective values of the soil saturation concentration, a relatively large initial time-step interval, and maximum and minimum change in mass should be specified (e.g., 4 days, 10%, and 5%, respectively). For comparison, the value of the soil saturation concentration (C_{sat}) for each chemical specified by the user may be found in the CHEMPROPS worksheet after all data have been entered on the DATENTER worksheet. If, however, the soil concentrations of the most volatile constituents are very close to their respective saturation limits, large values of the initial time-step interval, and the maximum and minimum change in mass will result in the error message in Figure 3 after starting the model.

Figure 3. Time-Step and Change in Mass Error Message

Re-set Values!

⊗ The initial time-step, maximum and minimum change in mass values are too high for successful completion of the calculations. Reduce these values and re-run the model.

OK
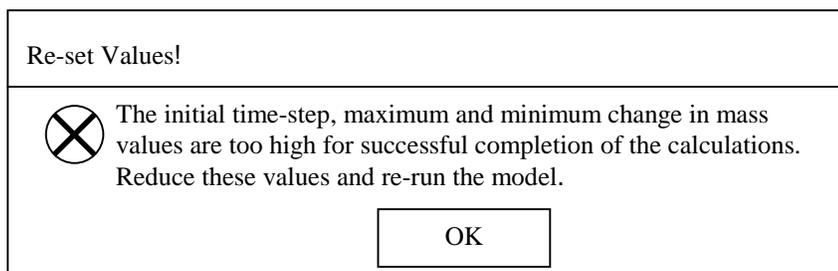
Should this error message occur, reduce the value of the initial time-step interval and the values of the maximum and minimum change in mass to smaller values and re-run the model. The error message will be repeated until the values of these variables are sufficiently small.

After all required data are entered into the DATENTER worksheet, the model is run by clicking on the "Execute Model" button which will change from reading "Execute" to "Stand by...". In addition, the message box in Figure 4 will appear keeping a running count of the number of residual phase time-step solutions achieved by the model.

Figure 4. Progress of Calculations Message Box

Progress of Calculations
Number of residual phase time-step solutions:
1
To stop calculations early, press CTRL + BREAK.

Each SOLVER trial solution can also be seen running in the status bar at the bottom of the screen. When the model is finished calculating, the "Execute Model" button will read "Done" and the Progress of Calculations message box in Figure 4 will disappear. The time-averaged building concentrations, incremental cancer risks, and/or hazard quotients will then be displayed under the "RESULTS" section of the DATENTER worksheet. In addition, an "X" will appear beside the calculated risk or hazard quotient of each contaminant for which a route-to-route extrapolation was employed. It should be noted that a route-to-route extrapolation was used for any chemical without a unit risk factor (URF) or a reference concentration (RfC). Therefore, the user should evaluate the resulting cancer risks and/or hazard quotients of such chemicals. Once a solution has been achieved and the user wishes to save the results, the file should be saved under a new file name. If the user wishes to delete <u>all</u> of the data previously entered on the DATENTER worksheet, this may be accomplished by clicking on the "Clear Data Entry Sheet" button.

Stopping Calculations Early

As mentioned previously, the user-defined values of the initial time-step interval, and the maximum and minimum change in mass should be chosen carefully. If the model run-time is excessive or if the user simply wishes to terminate the calculations, the model may be stopped by pressing CTRL + BREAK. If termination occurs in-between SOLVER solutions, the message box in Figure 5 will appear.

Figure 5. Code Interruption Message Box

Microsoft Visual Basic
Code execution has been interrupted
Continue	End	Debug	Help
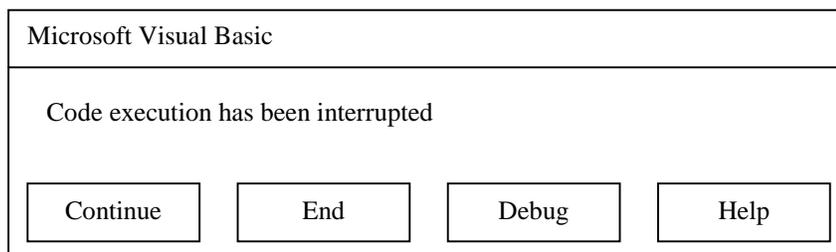
If this message box appears, click on the "End" button to terminate the macro.

If the termination occurs during a SOLVER solution, the message box in Figure 6 will appear. If this message box appears, click on the "Stop" button. This will stop the SOLVER solution but not the program macro. Depending on where in the macro code the interruption occurs, the model may continue to operate after clicking on the "Stop" button in Figure 6. If this happens, press CTRL + BREAK again. At this point, the message box in Figure 5 will appear; click on the "End" button to terminate the macro.

Figure 6. Solver Interruption Message Box

Show Trial Solution	
Solver paused, current solution values displayed on worksheet	Continue
	Stop
Save Scenario...	Help
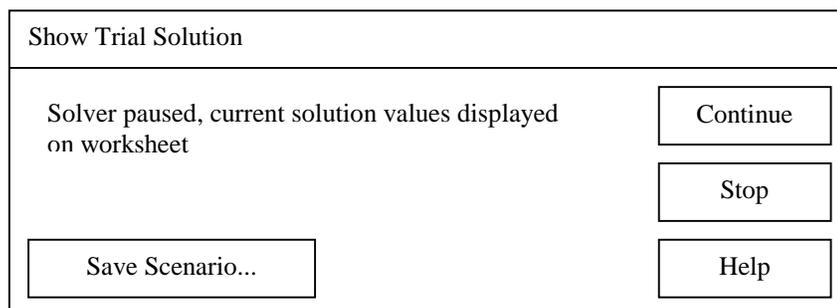
At this point, the user may examine the model results up to the point of termination on the COMPUTE worksheet. The values of the "Change in mass", the "Time-step interval", and the "Cumulative time" should be examined to determine if changes are necessary in the values of the initial time-step interval, and the maximum and minimum change in mass. After these or any other values are changed on the DATENTER worksheet, the model may be re-run by clicking on the "Execute Model" button.

Step-By-Step Procedures for Running the Models

The following gives the step-by-step procedures for running either the NAPL-SCREEN or the NAPL-ADV model.

1. On the DATENTER worksheet, enter the CAS number of each soil contaminant in the residual phase mixture (do not include dashes in the CAS numbers). After the CAS numbers have been entered, the respective chemical names will appear in the "Chemical" box.

2. On the DATENTER worksheet, enter the soil concentration of each contaminant in units of <u>mg/kg</u> as well as values for all remaining variables except the "Initial time-step", the "Maximum change in mass", and the "Minimum change in mass".

3. On the CHEMPROPS worksheet, note the calculated values of the "Time to steady state" (τ_{ss}) for each contaminant. Calculated values of the time-averaged building concentration and associated risks for contaminants with values of τ_{ss} greater than the actual elapsed time since initial soil contamination will be artificially high.

4. On the CHEMPROPS worksheet, note the calculated values of the "Soil saturation concentration" (C_{sat}) for each contaminant. Use these data to help determine appropriate user-defined values for the initial time-step, and the maximum and minimum change in mass. Typical values for these variables might be 2 days, 7%, and 4%, respectively, but may be considerably higher or lower depending on the number of chemicals in the analysis and the starting soil concentrations (see the discussion on page 8).

5. Click on the "Execute Model" button to begin the model calculations. If data are missing on the DATENTER worksheet, or entered values do not conform to model assumptions, an error message box will appear after the model is started informing the user of the type of error encountered. Enter the appropriate values on the DATENTER worksheet and re-run the model. Once the model has successfully started, note the number of residual phase time-step solutions achieved by the model in the Progress of Calculations message box (Figure 4). Use this information to help establish new values for the initial time-step interval and the maximum and minimum change in mass if the number of time-steps needs to be increased or decreased.

6. When the NAPL-SCREEN model has finished calculating, check column "O" on the COMPUTE worksheet to determine how many time-steps were calculated while a residual phase was present; one time-step is equal to one row (when using the NAPL-ADV model check column "P"). A residual phase is present when the value in column "O" or "P", as appropriate, is equal to 1.000. In general, a greater number of time-steps means a more accurate estimate of the time-averaged building concentration. If the starting soil concentrations of the most volatile contaminants are very close to their respective values of C_{sat}, a minimum of 5 to 10 time-steps should be calculated by the model. For all other cases, a reasonable number of time-steps is between 40 and 70. To increase the number of time-steps calculated by the model, decrease the values of the initial time-step interval and the maximum and minimum change in mass. The opposite is true when the number of time-steps is to be decreased.

7. If the message box in Figure 1 appears after starting the model, the mixture of compounds and concentrations specified does not include a residual phase. Use the SL-SCREEN or SL-ADV model to calculate indoor air concentrations and risks for each contaminant separately.

8. If the message box in Figure 3 appears after starting the model, reduce the input values of the initial time-step, and maximum and minimum change in mass and re-run the model.

9. If the run-time of the model is excessive, terminate the model macro by pressing CTRL + BREAK (see the discussion under **Stopping Calculations Early** on pages 9 and 10). Examine the calculated values of the "Change in mass", the "Time-step interval", and the "Cumulative time" on the COMPUTE worksheet. Re-enter new lower values for the initial time-step interval, and the maximum and minimum change in mass and re-run the model.

10. After successful completion of a model run, note the calculated values of the "Time-averaged building concentration", "Incremental cancer risk", and/or "Hazard quotient" in the "RESULTS" section of the DATENTER worksheet. Also note for which contaminants a route-to-route extrapolation was employed. <u>If the model results are to be retained, save the file under a new file name</u>.

Adding, Deleting or Revising Chemical Data

Additional chemicals can be listed in the "Chemical Properties Lookup Table" within the VLOOKUP worksheet. To add, delete or revise chemicals, the VLOOKUP worksheet must be unprotected using the password "ABC" in capital letters. Row number 171 is the last row that may be used to add new chemicals. If new chemicals are added or chemicals deleted, the user must sort all the data in the "Chemical Properties Lookup Table" (except the column headers) in ascending order by CAS number. After sorting is complete, the worksheet should again be protected.

APPENDIX B

CHEMICAL PROPERTIES LOOKUP TABLE AND REFERENCES

CAS No.	Chemical	Organic Carbon Partition Coefficient Koc (cm³/g)	Diffusivity in Air Da (cm²/s)	Diffusivity in Water Dw (cm²/s)	Pure Component Water Solubility S (mg/L)	Henry's Law Constant H' (unitless)	Henry's Law Constant at Reference Temperature H (atm-m³/mol)	Henry's Law Constant Reference Temperature TR (°C)	Normal Boiling Point TB (°K)	Critical Temperature TC (°K)	Enthalpy of Vaporization at the Normal Boiling Point deltaHv,b (cal/mol)	Unit Risk Factor URF (ug/m³)⁻¹	Reference Concentration RfC (mg/m³)	Density ri (g/cm³)	Physical State at soil Temp (S,L,G)	Vapor Pressure VP (mm Hg)	Molecular Weight Mw (g/mole)	URF extrapolated (X)	Rfc extrapolated (X)
74873	Methyl chloride (chlorome	2.12E+00 2	1.26E-01 2	6.50E-06 2	5.33E+03 3	3.61E-01 3	8.80E-03	25	249.00 4	416.25 4	5.11E+03 4	1.00E-06 3	9.00E-02 3	0.9159 8	L	4.30E+03 5	5.05E+01 3		
74908	Hydrogen cyanide	3.80E+00 2	1.93E-01 2	2.10E-05 2	1.00E+06 3	5.44E-03 3	1.33E-04	25	299.00 4	456.70 4	6.68E+03 7		3.00E-03 3	0.6876 4	L	7.42E+02 5	2.70E+01 3		
74953	Methylene bromide	1.26E+01 2	4.30E-02 2	8.44E-06 2	1.19E+04 3	3.52E-02 3	8.59E-04	25	370.00 4	583.00 6	7.87E+03 4		3.50E-02 3	2.4969 4	L	4.44E+01 5	1.74E+02 3		X
75003	Chloroethane (ethyl chlori	4.40E+00 2	2.71E-01 2	1.15E-05 2	5.68E+03 3	3.61E-01 3	8.80E-03	25	285.30 4	460.40 4	5.88E+03 4	8.29E-07 3	1.00E+01 3	0.3242 8	L	1.01E+03 5	6.45E+01 3	X	
75014	Vinyl chloride (chloroethen	1.86E+01 1	1.06E-01 1	1.23E-05 1	8.80E+03 3	1.10E+00 1	2.69E-02	25	2.59E+02 1	4.32E+02 1	5.25E+03 1	8.80E-06 1	1.00E-01 3	9.11E-01 4	G	2.98E+03 5	6.25E+01 3		
75058	Acetonitrile	4.20E+00 2	1.28E-01 2	1.66E-05 2	1.00E+06 3	1.42E-03 3	3.45E-05	25	354.60 4	545.50 4	7.11E+03 4		6.00E-02 3	0.7857 4	L	9.11E+01 5	4.11E+01 3		
75070	Acetaldehyde	1.06E+00 2	1.24E-01 2	1.41E-05 2	1.00E+06 3	3.23E-03 3	7.87E-05	25	293.10 4	466.00 4	6.16E+03 4	2.20E-06 3	9.00E-03 3	0.783 4	L	9.02E+02 5	4.41E+01 3		
75092	Methylene chloride	1.17E+01 1	1.01E-01 1	1.17E-05 1	1.30E+04 3	8.96E-02 3	2.18E-03	25	3.13E+02 1	5.10E+02 1	6.71E+03 1	4.70E-07 3	3.01E+00 3	1.33E+00 4	L	4.33E+02 5	8.49E+01 3		
75150	Carbon disulfide	4.57E+01 1	1.04E-01 1	1.00E-05 1	1.19E+03 3	1.24E+00 3	3.02E-02	25	3.19E+02 1	5.52E+02 1	6.39E+03 1		7.00E-01 3	1.26E+00 4	L	3.59E+02 5	7.61E+01 3		
75218	Ethylene oxide	1.33E+00 2	1.04E-01 2	1.45E-05 2	3.04E+05 3	2.27E-02 3	5.54E-04	25	283.60 4	469.00 4	6.10E+03 4	1.00E-04 3		0.3146 4	L	1.25E+03 5	4.41E+01 3		
75252	Bromoform	8.71E+01 1	1.49E-02 2	1.03E-05 1	3.10E+03 3	2.41E-02 3	5.88E-04	25	4.22E+02 1	6.96E+02 1	9.48E+03 1	1.10E-06 3	7.00E-02 3	2.90E+00 4	L	5.51E+00 5	2.53E+02 3		X
75274	Bromodichloromethane	5.50E+01 1	2.98E-02 2	1.06E-05 1	6.74E+03 3	6.54E-02 3	1.60E-03	25	3.63E+02 1	5.86E+02 1	7.80E+03 1	1.77E-05 3	7.00E-02 3	1.98E+00 4	L	5.00E+01 5	1.64E+02 3	X	X
75296	2-Chloropropane	9.14E+00 2	8.88E-02 2	1.01E-05 2	3.73E+03 3	5.93E-01 3	1.45E-02	25	308.70 4	485.00 6	6.29E+03 4		1.02E-01 3	0.8617 4	L	5.23E+02 5	7.85E+01 3		
75343	1,1-Dichloroethane	3.16E+01 1	7.42E-02 2	1.05E-05 2	5.06E+03 3	2.30E-01 3	5.61E-03	25	3.31E+02 1	5.23E+02 1	6.90E+03 1		5.00E-01 3	1.18E+00 4	L	2.27E+02 5	9.90E+01 3		
75354	1,1-Dichloroethylene	5.89E+01 1	9.00E-02 1	1.04E-05 1	2.25E+03 3	1.07E+00 3	2.60E-02	25	3.05E+02 1	5.76E+02 1	6.25E+03 1		2.00E-01 3	1.21E+00 4	L	6.00E+02 5	9.69E+01 3		
75456	Chlorodifluoromethane	4.79E+01 2	1.01E-01 2	1.28E-05 2	2.00E+00 3	1.10E+00 3	2.70E-02	25	232.40 4	369.30 4	4.84E+03 6		5.00E+01 3	1.209 8	L	7.48E+03 5	8.65E+01 3		
75694	Trichlorofluoromethane	4.97E+02 2	8.70E-02 2	9.70E-06 2	1.10E+03 3	3.97E+00 3	9.68E-02	25	296.70 4	471.00 6	6.00E+03 6*		7.00E-01 3	1.4879 8	L	8.03E+02 5	1.37E+02 3		
75718	Dichlorodifluoromethane	4.57E+02 2	6.65E-02 2	9.92E-06 2	2.80E+02 3	1.40E+01 3	3.42E-01	25	243.20 4	384.95 4	9.42E+03 6		2.00E-01 3	1.33 8	L	4.85E+03 5	1.21E+02 3		
76131	1,1,2-Trichloro-1,2,2-triflu	1.11E+04 2	7.80E-02 2	8.20E-06 2	1.70E+02 3	1.97E+01 3	4.80E-01	25	320.70 4	487.30 4	6.46E+03 4*		2.00E-01 3	1.5635 8	L	3.32E+02 5	1.87E+02 3		
76448	Heptachlor	1.41E+06 1	1.12E-02 2	5.69E-06 1	1.80E-01 3	6.05E+01 3	1.48E+00	25	6.04E+02 1	8.46E+02 1	1.30E+04 1	1.30E-03 3	1.75E-03	NA	S	4.00E-04 5	3.73E+02 3		
77474	Hexachlorocyclopentadien	2.00E+05 1	1.61E-02 2	7.21E-06 1	1.80E+00 3	1.10E+00 3	2.69E-02	25	5.12E+02 1	7.46E+02 1	1.09E+04 1		2.00E-04 3	1.70E+00 4	L	6.00E-02 5	2.73E+02 3		X
78831	Isobutanol	2.59E+00 2	8.60E-02 2	9.30E-06 2	8.50E+04 3	4.83E-04 3	1.18E-05	25	381.04 4	547.78 4	1.09E+04 6		1.05E+00 4	0.8018 4	L	1.05E+01 5	7.41E+01 3		X
78875	1,2-Dichloropropane	4.37E+01 1	7.82E-02 2	8.73E-06 1	2.80E+03 3	1.15E-01 3	2.79E-03	25	3.70E+02 1	5.72E+02 1	7.59E+03 1	1.94E-05 3	4.00E-03 3	1.13E+00 4	L	5.20E+01 5	1.13E+02 3	X	
78933	Methylethylketone (2-buta	2.30E+00 2	8.08E-02 2	9.80E-06 2	2.23E+05 3	2.29E-03 3	5.58E-05	25	352.50 4	536.78 4	7.48E+03 4		1.00E+00 3	0.8054 4	L	9.53E+01 5	7.21E+01 3		
79005	1,1,2-Trichloroethane	5.01E+01 1	7.80E-02 1	8.80E-06 1	4.42E+03 3	3.73E-02 3	9.11E-04	25	3.86E+02 1	6.02E+02 1	8.32E+03 1	1.60E-05 3	1.40E+00 4	L	2.33E+01 5	1.33E+02 3		X
79016	Trichloroethylene	1.66E+02 1	7.90E-02 1	9.10E-06 1	1.47E+03 3	4.21E-01 3	1.03E-02	25	3.60E+02 1	5.44E+02 1	7.51E+03 1	1.10E-04 3	4.00E-02 3	1.46E+00 4	L	7.35E+01 5	1.31E+02 3	X	
79209	Methyl acetate	3.26E+00 2	1.04E-01 2	1.00E-05 2	2.00E+03 3	4.84E-03 3	1.18E-04	25	329.80 4	506.70 4	7.26E+03 6		3.50E+00 3	0.9342 4	L	2.35E+02 5	7.41E+01 3		X
79345	1,1,2,2-Tetrachloroethane	9.33E+01 1	7.10E-02 2	7.90E-06 1	2.96E+03 3	1.41E-02 3	3.44E-04	25	4.20E+02 1	6.61E+02 1	9.00E+03 1	5.80E-05 3	2.10E-01	1.60E+00 4	L	4.62E+00 5	1.68E+02 3		X
79469	2-Nitropropane	1.17E+01 2	9.23E-02 2	1.01E-05 2	1.70E+04 3	5.03E-03 3	1.23E-04	25	393.20 4	594.00 4	8.38E+03 4	2.69E-03 3	2.00E-02 3	0.9876 4	L	1.80E+01 5	8.91E+01 3		
80626	Methylmethacrylate	6.98E+00 2	7.70E-02 2	8.60E-06 2	1.50E+04 3	1.38E-02 3	3.36E-04	25	373.50 4	567.00 4	8.97E+03 6		7.00E-01 3	0.944 4	L	3.84E+01 5	1.00E+02 3		
83329	Acenaphthene	7.08E+03 1	4.21E-02 2	7.69E-06 1	3.57E+00 3	6.34E-03 3	1.55E-04	25	5.51E+02 1	8.03E+02 1	1.22E+04 1		2.10E-01 3	NA	S	2.50E-03 5	1.54E+02 3		X
86737	Fluorene	1.38E+04 1	3.63E-02 2	7.88E-06 1	1.98E+00 3	2.60E-03 3	6.34E-05	25	5.70E+02 1	8.70E+02 1	1.27E+04 1		1.40E-01 3	NA	S	6.33E-04 5	1.66E+02 3		X
87683	Hexachloro-1,3-butadiene	5.37E+04 1	5.61E-02 2	6.16E-06 1	3.20E+00 3	3.33E-01 3	8.13E-03	25	4.86E+02 1	7.38E+02 1	1.02E+04 1	2.20E-05 3	7.00E-04 3	1.56E+00 4	L	2.21E-01 5	2.61E+02 3		X
88722	o-Nitrotoluene	3.24E+02 2	5.87E-02 2	8.67E-06 2	6.50E+02 3	5.11E-04 3	1.25E-05	25	495.00 4	720.00 8	1.22E+04 6		3.50E-02 3	1.163 8	L	4.50E-01 5	1.37E+02 3		X
91203	Naphthalene	2.00E+03 1	5.90E-02 1	7.50E-06 1	3.10E+01 3	1.98E-02 3	4.82E-04	25	4.91E+02 1	7.48E+02 1	1.04E+04 1		3.00E-03 3	NA	S	8.50E-02 5	1.28E+02 3		
91576	2-Methylnaphthalene	2.81E+03 1	5.22E-02 2	7.75E-06 2	2.46E+01 3	2.12E-02 3	5.17E-04	25	514.26 4	761.00 4	1.26E+04 4		7.00E-02 3	1.0058 4	S	5.50E-02 5	1.42E+02 3		
92524	Biphenyl	4.38E+03 1	4.04E-02 2	8.15E-06 2	7.45E+00 3	1.23E-02 3	2.99E-04	25	529.10 4	789.00 4	1.09E+04 4		1.75E-01 3	1.04 4	S	9.64E-03 5	1.54E+02 3		
95476	o-Xylene	3.63E+02 1	8.70E-02 1	1.00E-05 1	1.78E+02 3	2.12E-01 3	5.18E-03	25	4.18E+02 1	6.30E+02 1	8.66E+03 1		7.00E+00 3	8.80E-01 4	L	6.61E+00 5	1.06E+02 3		
95501	1,2-Dichlorobenzene	6.17E+02 1	6.90E-02 1	7.90E-06 1	1.56E+02 3	7.77E-02 3	1.90E-03	25	4.54E+02 1	7.05E+02 1	9.70E+03 1		2.00E-01 3	1.31E+00 4	L	1.36E+00 5	1.47E+02 3		
95578	2-Chlorophenol	3.88E+02 1	5.01E-02 2	9.46E-06 1	2.20E+04 3	1.60E-02 3	3.90E-04	25	4.48E+02 1	6.75E+02 1	9.57E+03 1		1.75E-02 3	1.26E+00 4	L	2.34E+00 5	1.29E+02 3		X
95636	1,2,4-Trimethylbenzene	1.35E+03 2	6.06E-02 2	7.92E-06 2	5.70E+01 3	2.52E-01 3	6.14E-03	25	442.30 4	649.17 4	9.37E+03 6		5.95E-03 3	0.8758 4	L	2.10E+00 5	1.20E+02 3		
96184	1,2,3-Trichloropropane	2.20E+01 2	7.10E-02 2	7.90E-06 2	1.75E+03 3	1.67E-02 3	4.08E-04	25	430.00 4	652.00 6	9.17E+03 8	5.71E-04 3	4.90E-03 3	1.3889 4	L	3.69E+00 5	1.47E+02 3	X	
96333	Methyl acrylate	4.53E+00 2	9.76E-02 2	1.02E-05 2	6.00E+04 3	7.68E-03 3	1.87E-04	25	353.70 4	536.00 7	7.75E+03 7		1.05E-01 3	0.9535 4	L	8.80E+01 5	8.61E+01 3		X
97632	Ethylmethacrylate	2.95E+01 2	6.53E-02 2	8.37E-06 2	3.67E+03 3	3.44E-02 3	8.40E-04	25	390.00 4	571.00 4	1.10E+04 6		3.15E-01 3	0.9135 4	L	2.06E+01 5	1.14E+02 3		X
98066	tert-Butylbenzene	7.71E+02 2	5.65E-02 2	8.02E-06 2	2.95E+01 3	4.87E-01 3	1.19E-02	25	442.10 4	1220.00 9	8.98E+03 8		1.40E-01 3	0.8665 4	L	2.20E+00 5	1.34E+02 3		X
98828	Cumene	4.89E+02 2	6.50E-02 2	7.10E-06 2	6.13E+01 3	4.74E+01 3	1.16E+00	25	425.56 4	631.10 4	1.03E+04 6		4.00E-01 3	0.8618 4	L	4.50E+00 5	1.20E+02 3		
98862	Acetophenone	5.77E+01 2	6.00E-02 2	8.73E-06 2	6.13E+03 3	4.38E-04 3	1.07E-05	25	475.00 4	709.50 4	1.17E+04 6		3.50E-01 3	1.0281 4	S,L	3.97E-01 5	1.20E+02 3		X
98953	Nitrobenzene	6.46E+01 1	7.60E-02 1	8.60E-06 1	2.09E+03 3	9.82E-04 3	2.39E-05	25	4.84E+02 1	7.19E+02 1	1.06E+04 1		2.00E-03 3	1.20E+00 4	L	2.45E-01 5	1.23E+02 3		
100414	Ethylbenzene	3.63E+02 1	7.50E-02 1	7.80E-06 1	1.69E+02 3	3.22E-01 3	7.86E-03	25	4.09E+02 1	6.17E+02 1	8.50E+03 1	1.10E-06 3	1.00E+00 3	8.67E-01 4	L	9.60E+00 5	1.06E+02 3		
100425	Styrene	7.76E+02 1	7.10E-02 1	8.00E-06 1	3.10E+02 3	1.12E-01 3	2.74E-03	25	4.18E+02 1	6.36E+02 1	8.74E+03 1		1.00E+00 3	9.06E-01 4	L	6.12E+00 5	1.04E+02 3		
100447	Benzylchloride	6.14E+01 2	7.50E-02 2	7.80E-06 2	5.25E+02 3	1.70E-02 3	4.14E-04	25	452.00 4	685.00 8	8.77E+03 6	4.86E-05 3		1.1004 4	L	1.31E+00 5	1.27E+02 3	X	
100527	Benzaldehyde	4.59E+01 2	7.21E-02 2	9.07E-06 2	3.30E+03 3	9.73E-04 3	2.37E-05	25	452.00 4	695.00 4	1.17E+04 6		3.50E-01 3	1.0415 4	L	9.00E-01 5	1.06E+02 3		
103651	n-Propylbenzene	5.62E+02 2	6.01E-02 2	7.83E-06 2	6.00E+01 3	4.37E-01 3	1.07E-02	25	432.20 4	630.00 4	9.12E+03 8		1.40E-01 3	0.862 4	L	2.50E+00 5	1.20E+02 3		
104518	n-Butylbenzene	1.11E+03 2	5.70E-02 2	8.12E-06 2	2.00E+00 3	5.38E-01 3	1.31E-02	25	456.46 4	660.50 4	9.29E+03 4		4.00E-01 3	0.8601 4	L	1.00E+00 5	1.34E+02 3		X
106423	p-Xylene	3.89E+02 1	7.69E-02 1	8.44E-06 1	1.85E+02 3	3.13E-01 3	7.64E-03	25	4.12E+02 1	6.16E+02 1	8.53E+03 1		7.00E+00 3	8.61E-01 4	L	8.90E+00 5	1.06E+02 3		
106467	1,4-Dichlorobenzene	6.17E+02 1	6.90E-02 1	7.90E-06 1	7.90E+01 3	9.82E-02 3	2.39E-03	25	4.47E+02 1	6.85E+02 1	9.27E+03 1		8.00E-01 3	NA	S	1.00E+00 5	1.47E+02 3		
106934	1,2-Dibromoethane (ethyl	2.50E+01 2	2.17E-02 2	1.19E-05 2	4.18E+03 3	3.04E-02 3	7.41E-04	25	404.60 4	583.00 4	8.31E+03 4	2.20E-04 3	2.00E-04 3	2.1791 4	L	1.33E+01 5	1.88E+02 3		
106990	1,3-Butadiene	1.91E+01 2	2.49E-01 2	1.08E-05 2	7.35E+02 3	3.01E+00 3	7.34E-02	25	268.60 4	425.00 4	5.37E+03 4	2.80E-04 3		0.29315 4	G	2.11E+03 5	5.41E+01 3		
107028	Acrolein	2.76E+00 2	1.05E-01 2	1.22E-05 2	2.13E+05 3	4.99E-03 3	1.22E-04	25	325.60 4	506.00 8	6.73E+03 6		2.00E-05 3	0.84 4	L	2.74E+02 5	5.61E+01 3		
107062	1,2-Dichloroethane	1.74E+01 1	1.04E-01 1	9.90E-06 1	8.52E+03 3	4.00E-02 3	9.77E-04	25	3.57E+02 1	5.61E+02 1	7.64E+03 1	2.60E-05 3		1.24E+00 4	L	7.89E+01 5	9.90E+01 3		
107131	Acrylonitrile	5.90E+00 2	1.22E-01 2	1.34E-05 2	7.40E+04 3	4.21E-03 3	1.03E-04	25	350.30 4	519.00 4	7.79E+03 8	6.80E-05 3	2.00E-03 3	0.806 4	L	1.09E+02 5	5.31E+01 3		
108054	Vinyl acetate	5.25E+00 2	8.50E-02 2	9.20E-06 2	2.00E+04 3	2.09E-02 3	5.10E-04	25	3.46E+02 1	5.19E+02 1	7.80E+03 1		2.00E-01 3	9.32E-01 4	L	9.02E+01 5	8.61E+01 3		
108101	Methylisobutylketone (4-m	9.06E+00 2	7.50E-02 2	7.80E-06 2	1.90E+04 3	5.64E-03 3	1.38E-04	25	389.50 4	571.00 4	8.24E+03 4		8.00E-02 3	0.7978 4	L	1.99E+01 5	1.00E+02 3		
108383	m-Xylene	4.07E+02 1	7.00E-02 1	7.80E-06 1	1.61E+02 3	3.00E-01 3	7.32E-03	25	4.12E+02 1	6.17E+02 1	8.52E+03 1		7.00E+00 3	8.64E-01 4	L	8.45E+00 5	1.06E+02 3		
108678	1,3,5-Trimethylbenzene	1.35E+03 2	6.02E-02 2	8.67E-06 2	2.00E+00 3	2.41E-01 3	5.87E-03	25	437.89 4	637.25 4	9.32E+03 6		5.95E-03 3	0.8652 4	L	2.40E+00 5	1.20E+02 3		
108872	Methylcyclohexane	7.85E+01 2	7.35E-02 2	8.52E-06 2	1.40E+01 3	4.22E+00 3	1.03E-01	25	373.90 4	572.20 4	7.47E+03 4		3.01E+00 3	0.7694 4	L	4.30E+01 5	9.82E+01 3		
108883	Toluene	1.82E+02 1	8.70E-02 1	8.60E-06 1	5.26E+02 3	2.72E-01 3	6.62E-03	25	3.84E+02 1	5.92E+02 1	7.93E+03 1		4.00E-01 3	8.67E-01 4	L	2.84E+01 5	9.21E+01 3		
108907	Chlorobenzene	2.19E+02 1	7.30E-02 1	8.70E-06 1	4.72E+02 3	1.51E-01 3	3.69E-03	25	4.05E+02 1	6.32E+02 1	8.41E+03 1		5.95E-02 3	1.11E+00 4	L	1.20E+01 5	1.13E+02 3		
109693	1-Chlorobutane	1.72E+01 2	8.26E-02 2	1.00E-05 2	1.10E+03 3	6.93E-01 3	1.69E-02	25	351.60 4	542.00 4	7.26E+03 6		1.40E+00 5	0.8862 4	L	1.01E+02 5	9.26E+01 3		X
110009	Furan	1.86E+01 2	1.04E-01 2	1.22E-05 2	1.00E+04 3	2.21E-01 3	5.39E-03	25	304.60 4	490.20 4	6.48E+03 4		3.50E-03 3	0.9514 4	L	6.00E+02 5	6.81E+01 3		X
110543	Hexane	4.34E+01 2	2.00E-01 2	7.77E-06 2	1.24E+01 3	6.82E+01 3	1.66E+00	25	341.70 4	508.00 4	6.90E+03 4		2.00E-01 3	0.6548 4	L	1.51E+02 5	8.62E+01 3		
111444	Bis(2-chloroethyl)ether	1.55E+01 1	6.92E-02 2	7.53E-06 1	1.72E+04 3	7.36E-04 3	1.80E-05	25	4.51E+02 1	6.60E+02 1	1.08E+04 1	3.30E-04 3		1.22E+00 4	L	1.55E+00 5	1.43E+02 3		
115297	Endosulfan	2.14E+03 1	1.15E-02 2	4.55E-06 1	5.10E-01 3	4.58E-04 3	1.12E-05	25	6.74E+02 4	9.43E+02 1	1.40E+04 1		2.10E-02 3	NA	S	1.00E-05 5	4.07E+02 3		X
118741	Hexachlorobenzene	5.50E+04 1	5.42E-02 2	5.91E-06 1	5.00E-03 3	5.40E-02 3	1.32E-03	25	5.83E+02 4	8.25E+02 1	1.44E+04 1	4.60E-04 3	2.80E-03 3	NA	S	1.80E-05 5	2.85E+02 3		
120821	1,2,4-Trichlorobenzene	1.78E+03 1	3.00E-02 2	8.23E-06 1	4.88E+01 3	5.81E-02 3	1.42E-03	25	4.86E+02 1	7.25E+02 1	1.05E+04 1		2.00E-01 3	1.46E+00 4	L	4.31E-01 5	1.81E+02 3		
123739	Crotonaldehyde (2-butena	4.82E+00 2	9.56E-02 2	1.07E-05 2	3.69E+04 3	7.99E-04 3	1.95E-05	25	375.20 4	568.00 7	8.62E+03 5	0.00E+00 3		0.8516 4	L	7.81E+00 5	7.01E+01 3		X
124481	Chlorodibromomethane	6.31E+01 1	1.96E-02 2	1.05E-05 1	2.60E+03 3	3.20E-02 3	7.81E-04	25	4.16E+02 1	6.78E+02 1	5.90E+03 4	2.40E-05 3	7.00E-02 3	2.45E+00 4	L	4.90E+00 5	2.08E+02 3	X	X
126987	Methacrylonitrile	3.58E+01 2	1.12E-01 2	1.32E-05 2	2.54E+04 3	1.01E-02 3	2.46E-04	25	363.30 4	554.00 4	7.60E+03 6		7.00E-04 3	0.8001 4	L	7.12E+01 5	6.71E+01 3		
126998	2-Chloro-1,3-butadiene (c	6.73E+01 2	8.58E-02 2	1.03E-05 2	2.12E+03 3	4.91E-01 3	1.20E-02	25	332.40 4	525.00 7	8.07E+03 7		7.00E-03 3	0.956 4	L	2.18E+02 5	8.85E+01 3		
127184	Tetrachloroethylene	1.55E+02 1	7.20E-02 1	8.20E-06 1	2.00E+02 3	7.53E-01 3	1.84E-02	25	3.94E+02 1	6.20E+02 1	8.29E+03 1	3.00E-06 3		1.62E+00 4	L	1.86E+01 5	1.66E+02 3		
129000	Pyrene	1.05E+05 1	2.72E-02 2	7.24E-06 1	1.35E+00 3	4.50E-04 3	1.10E-05	25	6.68E+02 4	9.36E+02 1	1.44E+04 1		1.05E-01 3	NA	S	4.59E-06 5	2.02E+02 3		X
132649	Dibenzofuran	5.15E+03 2	2.38E-02 2	6.00E-06 2	3.10E+00 3	5.15E-04 3	1.26E-05	25	560.00 4	824.00 6	6.64E+04 6*	0.00E+00 3	1.40E-02 3	1.1679 8	S	1.80E-04 5	1.68E+02 3		X

CAS No.	Chemical	Organic Carbon Partition Coefficient K_{oc} (cm³/g)		Diffusivity in Air D_a (cm²/s)		Diffusivity in Water D_w (cm²/s)		Pure Component Water Solubility S (mg/L)		Henry's Law Constant H' (unitless)		Henry's Law Constant at Reference Temperature H (atm-m³/mol)		Henry's Law Constant Reference Temperature T_R (°C)	Normal Boiling Point T_B (°K)		Critical Temperature T_C (°K)		Enthalpy of Vaporization at the Normal Boiling Point delta$H_{v,b}$ (cal/mol)		Unit Risk Factor URF (ug/m³)⁻¹		Reference Concentration RfC (mg/m³)		Density, r_l (g/cm³)		Physical State at soil Temp (S,L,G)	Vapor Pressure VP (mm Hg)	Molecular Weight M_w (g/mole)		URF extrapolated (X)	Rfc extrapolated (X)
135988	sec-Butylbenzene	9.66E+02	2	5.70E-02	2	8.12E-06	2	3.94E+00	3	5.68E-01	3	1.39E-02		25	446.50	4	679.00	9	8.87E+04	8	0.00E+00	3	1.40E-01	3	0.8621	8	L	3.10E-01	1.34E+02	3		X
141786	Ethylacetate	6.44E+00	2	7.32E-02	2	9.70E-06	2	8.03E+04	3	5.64E-03	3	1.38E-04		25	350.26	4	523.30	4	7.63E+03	4	0.00E+00	3	3.15E+00	3	0.9003	4	L	9.37E+01	8.81E+01	3		X
156592	cis-1,2-Dichloroethylene	3.55E+01	3	7.36E-02	1	1.13E-05	1	3.50E+03	3	1.67E-01	3	4.07E-03	3	25	3.34E+02	1	5.44E+02	1	7.19E+03	1	0.00E+00	3	3.50E-02	3	1.28E+00	4	L	2.03E+02	9.69E+01	3		X
156605	trans-1,2-Dichloroethylene	5.25E+01	1	7.07E-02	1	1.19E-05	1	6.30E+03	3	3.84E-01	3	9.36E-03	3	25	3.21E+02	1	5.17E+02	1	6.72E+03	1	0.00E+00	3	7.00E-02	3	1.26E+00	4	L	3.33E+02	9.69E+01	3		X
205992	Benzo(b)fluoranthene	1.23E+06	1	2.26E-02	1	5.56E-06	1	1.50E-03	3	4.54E-03	3	1.11E-04	3	25	7.16E+02	1	9.69E+02	1	1.70E+04	1	2.09E-04	1	NA		NA		S	5.00E-07	2.52E+02	3	X	
218019	Chrysene	3.98E+05	1	2.48E-02	1	6.21E-06	1	6.30E-03	3	3.87E-03	3	9.44E-05	3	25	7.14E+02	1	9.79E+02	1	1.65E+04	1	2.09E-06	3	0.00E+00	3	NA		S	6.23E-09	2.28E+02	3	X	
309002	Aldrin	2.45E+06	1	1.32E-02	1	4.86E-06	1	1.70E-02	3	6.95E-03	3	1.70E-04	3	25	6.03E+02	1	8.39E+02	1	1.50E+04	1	4.90E-03	3	1.05E-04	3	NA		S	6.00E-06	3.65E+02	3		X
319846	alpha-HCH (alpha-BHC)	1.23E+03	1	1.42E-02	1	7.34E-06	1	2.00E+00	3	4.34E-04	3	1.06E-05	3	25	5.97E+02	1	8.39E+02	1	1.50E+04	1	1.80E-03	3	0.00E+00	3	NA		S	4.50E-05	2.91E+02	3		
541731	1,3-Dichlorobenzene	1.98E+03	2	6.92E-02	2	7.86E-06	2	1.34E+02	3	1.27E-01	3	3.09E-03	3	25	446.00	8	684.00	8	9.23E+03	4	0.00E+00	3	1.05E-01	3	1.2884		L	2.15E+00	1.47E+02	3		X
542756	1,3-Dichloropropene	4.57E+01	1	6.26E-02	1	1.00E-05	1	2.80E+03	3	7.24E-01	3	1.77E-02	3	25	3.81E+02	1	5.87E+02	1	7.90E+03	1	4.00E-06	3	2.00E-02	3	1.22E+00	4	L	3.40E+01	1.11E+02	3		
1634044	MTBE	7.26E+00	2	1.02E-01	2	1.05E-05	2	5.10E+04	3	2.56E-02	3	6.23E-04	3	25	328.30	4	497.10	4	6.68E+03	4	0.00E+00	3	3.00E+00	3	0.7405	4	L	2.50E+02	8.82E+01	3		
7439976	Mercury (elemental)	5.20E+01	1	3.07E-02	1	6.30E-06	1	2.00E+01	3	4.40E-01	3	1.07E-02	3	25	6.30E+02	1	1.75E+03	1	1.41E+04	1	0.00E+00	3	3.00E-04	3	1.35E+01	4	L	2.00E-03	2.01E+02	3		

Sources:
1 User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion Into
  Buildings (Revised), December, 2000
2 Water9 Database
3 VI Draft Guidance, November 2002
4 CRC Handbook of Chemistry and Physics, 76th Edition
5 The Merck Index, 10th Edition
6 Hazardous Substances Data Bank, February 2003
  http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
7 Weiss, G., Hazardous Chemicals Data Book, Second Edition. Noyes Data Corporation. 1986.
8 DECHEMA Web Datbase, March 2003
  http://l-systems.dechema.de/
9 Flexware Engineering Solutions for Industry, Properties of Various Gases
  www.flexwareinc.com/gasprop.htm

* For enthalpy of vaporization, highlighted values are enthalpy of vaporization at value other than normal boiling point.
  For density, highlighted values are taken at temperature other than 20°C.

APPENDIX C

**EXAMPLE WORKSHEETS FOR THE ADVANCED SOIL
CONTAMINATION MODEL**

SL-ADV Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES | X |

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below

YES | |

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)		Chemica
71432			Benzene

	ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Totals must add up to value of L_t (cell G28) Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
MORE ↓	10	200	400	600	200	100	100	L		

	ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
MORE ↓	L	1.59	0.399	0.148	0.002	L	1.59	0.399	0.148	0.002	S	1.66	0.375	0.054	0.002

	ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space floor height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
MORE ↓	10	40	1000	1000	366	0.1	0.25	5

	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
	70	30	30	350	1.0E-06	1
END					Used to calculate risk-based soil concentration.	

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^{o}C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^{o}K)	Critical temperature, T_C (^{o}K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (μg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
8.80E-02	9.80E-06	5.54E-03	25	7,342	353.24	562.16	5.89E+01	1.79E+03	7.8E-06	0.0E+00	L

END

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm³/cm³)	Stratum B soil air-filled porosity, θ_a^B (cm³/cm³)	Stratum C soil air-filled porosity, θ_a^C (cm³/cm³)	Stratum A effective total fluid saturation, S_{te} (cm³/cm³)	Stratum A soil intrinsic permeability, k_i (cm²)	Stratum A soil relative air permeability, k_{rg} (cm²)	Stratum A soil effective vapor permeability, k_v (cm²)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm³/s)
9.46E+08	200	0.251	0.251	0.321	0.257	1.85E-09	0.854	1.58E-09	4,000	1.00E+00	2.54E+04

Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm²/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm²/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm²/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm²/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
1.80E+06	2.22E-04	200	8,122	2.68E-03	1.15E-01	1.75E-04	5.54E-03	5.54E-03	1.42E-02	7.97E-03	200	200

Soil-water partition coefficient, K_d (cm³/g)	Source vapor conc., C_{source} (µg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m³)	Finite source β term (unitless)	Finite source ψ term (sec)$^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
1.18E-01	6.68E+02	0.10	8.33E+01	5.54E-03	4.00E+02	2.06E+163	NA	NA	1.86E+00	8.02E-08	2.94E+07	YES

Finite source indoor attenuation coefficient, $<\alpha>$ (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m³)	Finite source bldg. conc., $C_{building}$ (µg/m³)	Final finite source bldg. conc., $C_{building}$ (µg/m³)	Unit risk factor, URF (µg/m³)$^{-1}$	Reference conc., RfC (mg/m³)
NA	2.49E-02	NA	2.49E-02	7.8E-06	NA

END

RESULTS SHEET

RISK-BASED SOIL CONCENTRATION CALCULATIONS: INCREMENTAL RISK CALCULATIONS:

Indoor exposure soil conc., carcinogen (μg/kg)	Indoor exposure soil conc., noncarcinogen (μg/kg)	Risk-based indoor exposure soil conc., (μg/kg)	Soil saturation conc., C_{sat} (μg/kg)	Final indoor exposure soil conc., (μg/kg)		Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.26E+01	NA	1.26E+01	3.09E+05	1.26E+01		NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

Soil Properties Lookup Table / Bulk Density

SCS Soil Type	K_s (cm/h)	α_1 (1/cm)	N (unitless)	M (unitless)	n (cm³/cm³)	θ_r (cm³/cm³)	Mean Grain Diameter (cm)	(g/cm³)	θ_w (cm³/cm³)	SCS Soil Name
C	0.61	0.01496	1.253	0.2019	0.459	0.098	0.0092	1.43	0.215	Clay
CL	0.34	0.01581	1.416	0.2938	0.442	0.079	0.016	1.48	0.168	Clay Loam
L	0.50	0.01112	1.472	0.3207	0.399	0.061	0.020	1.59	0.148	Loam
LS	4.38	0.03475	1.746	0.4273	0.390	0.049	0.040	1.62	0.076	Loamy Sand
S	26.78	0.03524	3.177	0.6852	0.375	0.053	0.044	1.66	0.054	Sand
SC	0.47	0.03342	1.208	0.1722	0.385	0.117	0.025	1.63	0.197	Sandy Clay
SCL	0.55	0.02109	1.330	0.2481	0.384	0.063	0.029	1.63	0.146	Sandy Clay Loam
SI	1.82	0.00658	1.679	0.4044	0.489	0.050	0.0046	1.35	0.167	Silt
SIC	0.40	0.01622	1.321	0.2430	0.481	0.111	0.0039	1.38	0.216	Silty Clay
SICL	0.46	0.00839	1.521	0.3425	0.482	0.090	0.0056	1.37	0.198	Silty Clay Loam
SIL	0.76	0.00506	1.663	0.3987	0.439	0.065	0.011	1.49	0.180	Silt Loam
SL	1.60	0.02667	1.449	0.3099	0.387	0.039	0.030	1.62	0.103	Sandy Loam

Chemical Properties Lookup Table

CAS No.	Chemical	Organic carbon partition coefficient, K_{oc} (cm³/g)	Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Pure component water solubility, S (mg/L)	Henry's law constant H' (unitless)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)	Physical state at soil temperature, (S,L,G)	URF extrapolated (X)	RfC extrapolated (X)
56235	Carbon tetrachloride	1.74E+02	7.80E-02	8.80E-06	7.93E+02	1.24E+00	3.03E-02	25	349.90	556.60	7,127	1.5E-05	0.0E+00	L		
57749	Chlordane	1.20E+05	1.18E-02	4.37E-06	5.60E-02	1.99E-03	4.85E-05	25	624.24	885.73	14,000	1.0E-04	7.0E-04	S		
58899	gamma-HCH (Lindane)	1.07E+03	1.42E-02	7.34E-06	7.30E+00	5.73E-04	1.40E-05	25	596.55	839.36	15,000	3.7E-04	1.1E-03	S	X	X
60297	Ethyl ether	5.73E+00	7.82E-02	8.61E-06	5.68E+04	1.35E-02	3.29E-02	25	307.50	466.74	6,338	0.0E+00	7.0E-01	L		X
60571	Dieldrin	2.14E+04	1.25E-02	4.74E-06	1.95E-01	6.18E-04	1.51E-05	25	613.32	842.25	17,000	4.6E-03	1.8E-04	S		X
67641	Acetone	5.75E-01	1.24E-01	1.14E-05	1.00E+06	1.59E-03	3.87E-05	25	329.20	508.10	6,955	0.0E+00	3.5E-01	L		X
67663	Chloroform	3.98E+01	1.04E-01	1.00E-05	7.92E+03	1.50E-01	3.66E-03	25	334.32	536.40	6,988	2.3E-05	0.0E+00	L		
67721	Hexachloroethane	1.78E+03	2.50E-03	6.80E-06	5.00E+01	1.59E-01	3.88E-03	25	458.00	695.00	9,510	4.0E-06	3.5E-03	S		X
71432	Benzene	5.89E+01	8.80E-02	9.80E-06	1.79E+03	2.27E-01	5.54E-03	25	353.24	562.16	7,342	7.8E-06	0.0E+00	L		
71556	1,1,1-Trichloroethane	1.10E+02	7.80E-02	8.80E-06	1.33E+03	7.03E-01	1.72E-02	25	347.24	545.00	7,136	0.0E+00	2.2E+00	L		
72435	Methoxychlor	9.77E+04	1.56E-02	4.46E-06	1.00E-01	6.46E-04	1.58E-05	25	651.02	848.49	16,000	0.0E+00	1.8E-02	S		X
72559	DDE	4.47E+06	1.44E-02	5.87E-06	1.20E-01	8.59E-04	2.09E-05	25	636.44	860.38	15,000	9.7E-05	0.0E+00	S	X	
74839	Methyl bromide	1.05E+01	7.28E-02	1.21E-05	1.52E+04	2.55E-01	6.22E-03	25	276.71	467.00	5,714	0.0E+00	5.0E-03	G		
74873	Methyl chloride (chloromethane)	2.12E+00	1.26E-01	6.50E-06	5.33E+03	3.61E-01	8.80E-03	25	249.00	416.25	5,115	1.0E-06	9.0E-02	L		
74908	Hydrogen cyanide	3.80E+00	1.93E-01	2.10E-05	1.00E+06	5.44E-03	1.33E-04	25	299.00	456.70	6,676	0.0E+00	3.0E-03	L		
74953	Methylene bromide	1.26E+01	4.30E-02	8.44E-06	1.19E+04	3.52E-02	8.59E-04	25	370.00	583.00	7,868	0.0E+00	3.5E-02	L		X
75003	Chloroethane (ethyl chloride)	4.40E+00	2.71E-01	1.15E-05	5.68E+03	3.61E-01	8.80E-03	25	285.30	460.40	5,879	8.3E-07	1.0E+01	L	X	
75014	Vinyl chloride (chloroethene)	1.86E+01	1.06E-01	1.23E-05	8.80E+03	1.10E+00	2.69E-02	25	259.25	432.00	5,250	8.8E-06	1.0E-01	G		
75058	Acetonitrile	4.20E+00	1.28E-01	1.66E-05	1.00E+06	1.42E-03	3.45E-05	25	354.60	545.50	7,110	0.0E+00	6.0E-02	L		
75070	Acetaldehyde	1.06E+00	1.24E-01	1.41E-05	1.00E+06	3.23E-03	7.87E-05	25	293.10	466.00	6,157	2.2E-06	9.0E-03	L		
75092	Methylene chloride	1.17E+01	1.01E-01	1.17E-05	1.30E+04	8.96E-02	2.18E-03	25	313.00	510.00	6,706	4.7E-07	3.0E+00	L		
75150	Carbon disulfide	4.57E+01	1.04E-01	1.00E-05	1.19E+03	1.24E+00	3.02E-02	25	319.00	552.00	6,391	0.0E+00	7.0E-01	L		
75218	Ethylene oxide	1.33E+00	1.04E-01	1.45E-05	3.04E+05	2.27E-02	5.54E-04	25	283.60	469.00	6,104	1.0E-04	0.0E+00	L		
75252	Bromoform	8.71E+01	1.49E-02	1.03E-05	3.10E+03	2.41E-02	5.88E-04	25	422.35	696.00	9,479	1.1E-06	7.0E-02	L		X
75274	Bromodichloromethane	5.50E+01	2.98E-02	1.06E-05	6.74E+03	6.54E-02	1.60E-03	25	363.15	585.85	7,800	1.8E-05	7.0E-02	L	X	X
75296	2-Chloropropane	9.14E+00	8.88E-02	1.01E-05	3.73E+03	5.93E-01	1.45E-02	25	308.70	485.00	6,286	0.0E+00	1.0E-01	L		
75343	1,1-Dichloroethane	3.16E+01	7.42E-02	1.05E-05	5.06E+03	2.30E-01	5.61E-03	25	330.55	523.00	6,895	0.0E+00	5.0E-01	L		
75354	1,1-Dichloroethylene	5.89E+01	9.00E-02	1.04E-05	2.25E+03	1.07E+00	2.60E-02	25	304.75	576.05	6,247	0.0E+00	2.0E-01	L		
75456	Chlorodifluoromethane	4.79E+01	1.01E-01	1.28E-05	2.00E+00	1.10E+00	2.70E-02	25	232.40	369.30	4,836	0.0E+00	5.0E+01	L		
75694	Trichlorofluoromethane	4.97E+02	8.70E-02	9.70E-06	1.10E+03	3.97E+00	9.68E-02	25	296.70	471.00	5,999	0.0E+00	7.0E-01	L		
75718	Dichlorodifluoromethane	4.57E+02	6.65E-02	9.92E-06	2.80E+02	1.40E+01	3.42E-01	25	243.20	384.95	9,421	0.0E+00	2.0E-01	L		
76131	1,1,2-Trichloro-1,2,2-trifluoroetha	1.11E+04	7.80E-02	8.20E-06	1.70E+02	1.97E+01	4.80E-01	25	320.70	487.30	6,463	0.0E+00	3.0E+01	L		
76448	Heptachlor	1.41E+06	1.12E-02	5.69E-06	1.80E-01	6.05E+01	1.48E+00	25	603.69	846.31	13,000	1.3E-03	1.8E-03	S		X
77474	Hexachlorocyclopentadiene	2.00E+05	1.61E-02	7.21E-06	1.80E+00	1.10E+00	2.69E-02	25	512.15	746.00	10,931	0.0E+00	2.0E-04	L		
78831	Isobutanol	2.59E+00	8.60E-02	9.30E-06	8.50E+04	4.83E-04	1.18E-05	25	381.04	547.78	10,936	0.0E+00	1.1E+00	L		X
78875	1,2-Dichloropropane	4.37E+01	7.82E-02	8.73E-06	2.80E+03	1.15E-01	2.79E-03	25	369.52	572.00	7,590	1.9E-05	4.0E-03	L	X	
78933	Methylethylketone (2-butanone)	2.30E+00	8.08E-02	9.80E-06	2.23E+05	2.29E-03	5.58E-05	25	352.50	536.78	7,481	0.0E+00	1.0E+00	L		
79005	1,1,2-Trichloroethane	5.01E+01	7.80E-02	8.80E-06	4.42E+03	3.73E-02	9.11E-04	25	386.15	602.00	8,322	1.6E-05	1.4E-02	L		X
79016	Trichloroethylene	1.66E+02	7.90E-02	9.10E-06	1.47E+03	4.21E-01	1.03E-02	25	360.36	544.20	7,505	1.1E-04	4.0E-02	L	X	
79209	Methyl acetate	3.26E+00	1.04E-01	1.00E-05	2.00E+03	4.84E-03	1.18E-04	25	329.80	506.70	7,260	0.0E+00	3.5E+00	L		X
79345	1,1,2,2-Tetrachloroethane	9.33E+01	7.10E-02	7.90E-06	2.96E+03	1.41E-02	3.44E-04	25	419.60	661.15	8,996	5.8E-05	2.1E-01	L		X
79469	2-Nitropropane	1.17E+01	9.23E-02	1.01E-05	1.70E+04	5.03E-03	1.23E-04	25	393.20	594.00	8,383	2.7E-03	2.0E-02	L		
80626	Methylmethacrylate	6.98E+00	7.70E-02	8.60E-06	1.50E+04	1.38E-02	3.36E-04	25	373.50	567.00	8,975	0.0E+00	7.0E-01	L		
83329	Acenaphthene	7.08E+03	4.21E-02	7.69E-06	3.57E+00	6.34E-03	1.55E-04	25	550.54	803.15	12,155	0.0E+00	2.1E-01	S		X
86737	Fluorene	1.38E+04	3.63E-02	7.88E-06	1.98E+00	2.60E-03	6.34E-05	25	570.44	870.00	12,666	0.0E+00	1.4E-01	S		X
87683	Hexachloro-1,3-butadiene	5.37E+04	5.61E-02	6.16E-06	3.20E+00	3.33E-01	8.13E-03	25	486.15	738.00	10,206	2.2E-05	7.0E-04	L		X
88722	o-Nitrotoluene	3.24E+02	5.87E-02	8.67E-06	6.50E+02	5.11E-04	1.25E-05	25	495.00	720.00	12,239	0.0E+00	3.5E-02	L		X
91203	Naphthalene	2.00E+03	5.90E-02	7.50E-06	3.10E+01	1.98E-02	4.82E-04	25	491.14	748.40	10,373	0.0E+00	3.0E-03	S		
91576	2-Methylnaphthalene	2.81E+03	5.22E-02	7.75E-06	2.46E+01	2.12E-02	5.17E-04	25	514.26	761.00	12,600	0.0E+00	7.0E-02	S		X
92524	Biphenyl	4.38E+03	4.04E-02	8.15E-06	7.45E+00	1.23E-02	2.99E-04	25	529.10	789.00	10,890	0.0E+00	1.8E-01	S		X
95476	o-Xylene	3.63E+02	8.70E-02	1.00E-05	1.78E+02	2.12E-01	5.18E-03	25	417.60	630.30	8,661	0.0E+00	7.0E+00	L		
95501	1,2-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	1.56E+02	7.77E-02	1.90E-03	25	453.57	705.00	9,700	0.0E+00	2.0E-01	L		
95578	2-Chlorophenol	3.88E+02	5.01E-02	9.46E-06	2.20E+04	1.60E-02	3.90E-04	25	447.53	675.00	9,572	0.0E+00	1.8E-02	L		X

95636	1,2,4-Trimethylbenzene	1.35E+03	6.06E-02	7.92E-06	5.70E+01	2.52E-01	6.14E-03	25	442.30	649.17	9,369	0.0E+00	6.0E-03	L		
96184	1,2,3-Trichloropropane	2.20E+01	7.10E-02	7.90E-06	1.75E+03	1.67E-02	4.08E-04	25	430.00	652.00	9,171	5.7E-04	4.9E-03	L	X	
96333	Methyl acrylate	4.53E+00	9.76E-02	1.02E-05	6.00E+04	7.68E-03	1.87E-04	25	353.70	536.00	7,749	0.0E+00	1.1E-01	L		X
97632	Ethylmethacrylate	2.95E+01	6.53E-02	8.37E-06	3.67E+03	3.44E-02	8.40E-04	25	390.00	571.00	10,957	0.0E+00	3.2E-01	L		X
98066	tert-Butylbenzene	7.71E+02	5.65E-02	8.02E-06	2.95E+01	4.87E-01	1.19E-02	25	442.10	1220.00	8,980	0.0E+00	1.4E-01	L		X
98828	Cumene	4.89E+02	6.50E-02	7.10E-06	6.13E+01	4.74E+01	1.16E+00	25	425.56	631.10	10,335	0.0E+00	4.0E-01	L		
98862	Acetophenone	5.77E+01	6.00E-02	8.73E-06	6.13E+03	4.38E-04	1.07E-05	25	475.00	709.50	11,732	0.0E+00	3.5E-01	S,L		X
98953	Nitrobenzene	6.46E+01	7.60E-02	8.60E-06	2.09E+03	9.82E-04	2.39E-05	25	483.95	719.00	10,566	0.0E+00	2.0E-03	L		
100414	Ethylbenzene	3.63E+02	7.50E-02	7.80E-06	1.69E+02	3.22E-01	7.86E-03	25	409.34	617.20	8,501	1.1E-06	1.0E+00	L		
100425	Styrene	7.76E+02	7.10E-02	8.00E-06	3.10E+02	1.12E-01	2.74E-03	25	418.31	636.00	8,737	0.0E+00	1.0E+00	L		
100447	Benzylchloride	6.14E+01	7.50E-02	7.80E-06	5.25E+02	1.70E-02	4.14E-04	25	452.00	685.00	8,773	4.9E-05	0.0E+00	L	X	
100527	Benzaldehyde	4.59E+01	7.21E-02	9.07E-06	3.30E+03	9.73E-04	2.37E-05	25	452.00	695.00	11,658	0.0E+00	3.5E-01	L		X
103651	n-Propylbenzene	5.62E+02	6.01E-02	7.83E-06	6.00E+01	4.37E-01	1.07E-02	25	432.20	630.00	9,123	0.0E+00	1.4E-01	L		X
104518	n-Butylbenzene	1.11E+03	5.70E-02	8.12E-06	2.00E+00	5.38E-01	1.31E-02	25	456.46	660.50	9,290	0.0E+00	1.4E-01	L		X
106423	p-Xylene	3.89E+02	7.69E-02	8.44E-06	1.85E+02	3.13E-01	7.64E-03	25	411.52	616.20	8,525	0.0E+00	7.0E-01	L		X
106467	1,4-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	7.90E+01	9.82E-02	2.39E-03	25	447.21	684.75	9,271	0.0E+00	8.0E-01	S		
106934	1,2-Dibromoethane (ethylene dib	2.50E+01	2.17E-02	1.19E-05	4.18E+03	3.04E-02	7.41E-04	25	404.60	583.00	8,310	2.2E-04	2.0E-04	L		
106990	1,3-Butadiene	1.91E+01	2.49E-01	1.08E-05	7.35E+02	3.01E+00	7.34E-02	25	268.60	425.00	5,370	2.8E-04	0.0E+00	L		
107028	Acrolein	2.76E+00	1.05E-01	1.22E-05	2.13E+05	4.99E-02	1.22E-04	25	325.60	506.00	6,731	0.0E+00	2.0E-05	L		
107062	1,2-Dichloroethane	1.74E+01	1.04E-01	9.90E-06	8.52E+03	4.00E-02	9.77E-04	25	356.65	561.00	7,643	2.6E-05	0.0E+00	L		
107131	Acrylonitrile	5.90E+00	1.22E-01	1.34E-05	7.40E+04	4.21E-03	1.03E-04	25	350.30	519.00	7,786	6.8E-05	2.0E-03	L		
108054	Vinyl acetate	5.25E+00	8.50E-02	9.20E-06	2.00E+04	2.09E-02	5.10E-04	25	345.65	519.13	7,800	0.0E+00	2.0E-01	L		
108101	Methylisobutylketone (4-methyl-2	9.06E+00	7.50E-02	7.80E-06	1.90E+04	5.64E-03	1.38E-04	25	389.50	571.00	8,243	0.0E+00	8.0E-02	L		
108383	m-Xylene	4.07E+02	7.00E-02	7.80E-06	1.61E+02	3.00E-01	7.32E-03	25	412.27	617.05	8,523	0.0E+00	7.0E-01	L		X
108678	1,3,5-Trimethylbenzene	1.35E+03	6.02E-02	8.67E-06	2.00E+00	2.41E-01	5.87E-03	25	437.89	637.25	9,321	0.0E+00	6.0E-03	L		
108872	Methylcyclohexane	7.85E+01	7.35E-02	8.52E-06	1.40E+01	4.22E+00	1.03E-01	25	373.90	572.20	7,474	0.0E+00	3.0E+00	L		
108883	Toluene	1.82E+02	8.70E-02	8.60E-06	5.26E+02	2.72E-01	6.62E-03	25	383.78	591.79	7,930	0.0E+00	4.0E-01	L		
108907	Chlorobenzene	2.19E+02	7.30E-02	8.70E-06	4.72E+02	1.51E-01	3.69E-03	25	404.87	632.40	8,410	0.0E+00	6.0E-02	L		
109693	1-Chlorobutane	1.72E+01	8.26E-02	1.00E-05	1.10E+03	6.93E-01	1.69E-02	25	351.60	542.00	7,263	0.0E+00	1.4E+00	L		X
110009	Furan	1.86E+01	1.04E-01	1.22E-05	1.00E+04	2.21E-01	5.39E-03	25	304.60	490.20	6,477	0.0E+00	3.5E-03	L		X
110543	Hexane	4.34E+01	2.00E-01	7.77E-06	1.24E+01	6.82E+01	1.66E+00	25	341.70	508.00	6,895	0.0E+00	2.0E-01	L		
111444	Bis(2-chloroethyl)ether	1.55E+01	6.92E-02	7.53E-06	1.72E+04	7.36E-04	1.80E-05	25	451.15	659.79	10,803	3.3E-04	0.0E+00	L		
115297	Endosulfan	2.14E+03	1.15E-02	4.55E-06	5.10E+01	4.58E-04	1.12E-05	25	674.43	942.94	14,000	0.0E+00	2.1E-02	S		X
118741	Hexachlorobenzene	5.50E+04	5.42E-02	5.91E-06	5.00E-03	5.40E-02	1.32E-03	25	582.55	825.00	14,447	4.6E-04	2.8E-03	S		X
120821	1,2,4-Trichlorobenzene	1.78E+03	3.00E-02	8.23E-06	4.88E+01	5.81E-02	1.42E-03	25	486.15	725.00	10,471	0.0E+00	2.0E-01	L		
123739	Crotonaldehyde (2-butenal)	4.82E+00	9.56E-02	1.07E-05	3.69E+04	7.99E-04	1.95E-05	25	375.20	568.00	9	5.4E-04	0.0E+00	L	X	
124481	Chlorodibromomethane	6.31E+01	1.96E-02	1.05E-05	2.60E+03	3.20E-02	7.81E-04	25	416.14	678.20	5,900	2.4E-05	7.0E-02	L	X	X
126987	Methacrylonitrile	3.58E+01	1.12E-01	1.32E-05	2.54E+04	1.01E-02	2.46E-04	25	363.30	554.00	7,600	0.0E+00	7.0E-04	L		
126998	2-Chloro-1,3-butadiene (chloropre	6.73E+01	8.58E-02	1.03E-05	2.12E+03	4.91E-01	1.20E-02	25	332.40	525.00	8,075	0.0E+00	7.0E-03	L		
127184	Tetrachloroethylene	1.55E+02	7.20E-02	8.20E-06	2.00E+02	7.53E-01	1.84E-02	25	394.40	620.20	8,288	3.0E-06	0.0E+00	L		
129000	Pyrene	1.05E+05	2.72E-02	7.24E-06	1.35E+00	4.50E-04	1.10E-05	25	667.95	936	14370	0.0E+00	1.1E-01	S		X
132649	Dibenzofuran	5.15E+03	2.38E-02	6.00E-06	3.10E+00	5.15E-04	1.26E-05	25	560	824	66400	0.0E+00	1.4E-02	S		X
135988	sec-Butylbenzene	9.66E+02	5.70E-02	8.12E-06	3.94E+00	5.68E-01	1.39E-02	25	446.5	679	88730	0.0E+00	1.4E-01	L		X
141786	Ethylacetate	6.44E+00	7.32E-02	9.70E-06	8.03E+04	5.64E-03	1.38E-04	25	350.26	523.3	7633.66	0.0E+00	3.2E+00	L		X
156592	cis-1,2-Dichloroethylene	3.55E+01	7.36E-02	1.13E-05	3.50E+03	1.67E-01	4.07E-03	25	333.65	544	7192	0.0E+00	3.5E-02	L		X
156605	trans-1,2-Dichloroethylene	5.25E+01	7.07E-02	1.19E-05	6.30E+03	3.84E-01	9.36E-03	25	320.85	516.5	6717	0.0E+00	7.0E-02	L		X
205992	Benzo(b)fluoranthene	1.23E+06	2.26E-02	5.56E-06	1.50E-03	4.54E-03	1.11E-04	25	715.9	969.27	17000	2.1E-04	0.0E+00	S	X	
218019	Chrysene	3.98E+05	2.48E-02	6.21E-06	6.30E-03	3.87E-03	9.44E-05	25	714.15	979	16455	2.1E-06	0.0E+00	S	X	
309002	Aldrin	2.45E+06	1.32E-02	4.86E-06	1.70E-02	6.95E-03	1.70E-04	25	603.01	839.37	15000	4.9E-03	1.1E-04	S		X
319846	alpha-HCH (alpha-BHC)	1.23E+03	1.42E-02	7.34E-06	2.00E+00	4.34E-04	1.06E-05	25	596.55	839.36	15000	1.8E-03	0.0E+00	S		
541731	1,3-Dichlorobenzene	1.98E+03	6.92E-02	7.86E-06	1.34E+02	1.27E-01	3.09E-03	25	446	684	9230.18	0.0E+00	1.1E-01	L		X
542756	1,3-Dichloropropene	4.57E+01	6.26E-02	1.00E-05	2.80E+03	7.24E-01	1.77E-02	25	381.15	587.38	7900	4.0E-06	2.0E-02	L		
1634044	MTBE	7.26E+00	1.02E-01	1.05E-05	5.10E+04	2.56E-02	6.23E-04	25	328.3	497.1	6677.66	0.0E+00	3.0E+00	L		
7439976	Mercury (elemental)	5.20E+01	3.07E-02	6.30E-06	2.00E+01	4.40E-01	1.07E-02	25	629.88	1750	14127	0.0E+00	3.0E-04	L		

APPENDIX D

SAMPLE DATA ENTRY SHEETS FOR EACH MODEL

SL-SCREEN
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES | X |

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES | |

ENTER Chemical CAS No. (numbers only, no dashes)	**ENTER** Initial soil conc., C_R (μg/kg)	Chemical
71432		Benzene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	**ENTER** Depth below grade to top of contamination, L_t (cm)	**ENTER** Average soil temperature, T_S (^oC)	**ENTER** Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	**ENTER** User-defined vadose zone soil vapor permeability, k_v (cm^2)
200	400	10	SCL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	**ENTER** Vadose zone soil dry bulk density, $\rho_b{}^A$ (g/cm^3)	**ENTER** Vadose zone soil total porosity, n^V (unitless)	**ENTER** Vadose zone soil water-filled porosity, $\theta_w{}^V$ (cm^3/cm^3)	**ENTER** Vadose zone soil organic carbon fraction, $f_{oc}{}^V$ (unitless)	**ENTER** Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
SCL	1.35	0.384	0.146	0.002	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	**ENTER** Averaging time for noncarcinogens, AT_{NC} (yrs)	**ENTER** Exposure duration, ED (yrs)	**ENTER** Exposure frequency, EF (days/yr)	**ENTER** Target risk for carcinogens, TR (unitless)	**ENTER** Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1
				Used to calculate risk-based soil concentration.	

END

SL-ADV
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES | X

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below

YES |

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)		Chemical
71432			Benzene

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm²)
10	200	400	600	200	100	100	L		

Totals must add up to value of L_t (cell G28)

MORE ↓

ENTER Stratum A SCS soil type	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B SCS soil type	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C SCS soil type	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
L	1.4	0.399	0.148	0.002	L	1.4	0.399	0.148	0.002	S	1.65	0.375	0.054	0.002

Lookup Soil Parameters (Stratum A) | Lookup Soil Parameters (Stratum B) | Lookup Soil Parameters (Stratum C)

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space floor height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	366	0.1	0.25	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

SG-SCREEN
Version 2.0; 02/03

Reset to
Defaults

Soil Gas Concentration Data

ENTER	ENTER	OR	ENTER	
Chemical CAS No. (numbers only, no dashes)	Soil gas conc., C_g ($\mu g/m^3$)		Soil gas conc., C_g (ppmv)	Chemical
71432			2.00E+01	Benzene

MORE ↓

ENTER	ENTER	ENTER	ENTER	OR	ENTER
Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	Soil gas sampling depth below grade, L_s (cm)	Average soil temperature, T_S (^oC)	Vadose zone SCS soil type (used to estimate soil vapor permeability)		User-defined vadose zone soil vapor permeability, k_v (cm^2)
200	400	10	L		

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER
Vandose zone SCS soil type (Lookup Soil Parameters)	Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	Vadose zone soil total porosity, n^V (unitless)	Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
L	1.4	0.399	0.148	5

MORE ↓

ENTER	ENTER	ENTER	ENTER
Averaging time for carcinogens, AT_C (yrs)	Averaging time for noncarcinogens, AT_{NC} (yrs)	Exposure duration, ED (yrs)	Exposure frequency, EF (days/yr)
70	30	30	350

END

SG-ADV
Version 2.0; 02/03

Reset to
Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
71432			2.00E+01	Benzene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^{o}C)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Totals must add up to value of Ls (cell F24) Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
200	400	10	200	100	100	L		

MORE ↓

ENTER Stratum A SCS soil type Lookup Soil Parameters	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type Lookup Soil Parameters	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type Lookup Soil Parameters	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
L	1.4	0.399	0.148	L	1.4	0.399	0.148	S	1.65	0.375	0.054

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm-s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1000	1000	366	0.1	0.25	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

DATA ENTRY SHEET (GW-SCREEN)

GW-SCREEN
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	**ENTER** Initial groundwater conc., C_W ($\mu g/L$)	Chemical
71432		Benzene

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	**ENTER** Depth below grade to water table, L_{WT} (cm)	**ENTER** SCS soil type directly above water table	**ENTER** Average soil/ groundwater temperature, T_S (^oC)		**ENTER** Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
200	400	SC	10		5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	**ENTER** User-defined vadose zone soil vapor permeability, k_v (cm^2)	**ENTER** Vadose zone SCS soil type (Lookup Soil Parameters)	**ENTER** Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	**ENTER** Vadose zone soil total porosity, n^V (unitless)	**ENTER** Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SCL			SCL	1.35	0.384	0.146

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	**ENTER** Target hazard quotient for noncarcinogens, THQ (unitless)	**ENTER** Averaging time for carcinogens, AT_C (yrs)	**ENTER** Averaging time for noncarcinogens, AT_{NC} (yrs)	**ENTER** Exposure duration, ED (yrs)	**ENTER** Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

END

D-6

GW-ADV
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES	X

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES	

ENTER	ENTER
Chemical CAS No. (numbers only, no dashes)	Initial groundwater conc., C_W (μg/L)

Chemical

71432	

Chemical: **Benzene**

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER		ENTER
	Depth			Totals must add up to value of L_{WT} (cell G28)				Soil		
	below grade				Thickness	Thickness				
Average	to bottom	Depth	Thickness	of soil	of soil	Soil		stratum A		User-defined
soil/	of enclosed	below grade	of soil	stratum B,	stratum C,	stratum	SCS	SCS		stratum A
groundwater	space floor,	to water table,	stratum A,	(Enter value or 0)	(Enter value or 0)	directly above	soil type	soil type	OR	soil vapor
temperature,	L_F	L_{WT}	h_A	h_B	h_C	water table,	directly above	(used to estimate		permeability,
T_S							water table	soil vapor		k_v
(^{o}C)	(cm)	(cm)	(cm)	(cm)	(cm)	(Enter A, B, or C)		permeability)		(cm^2)
10	200	400	300	50	50	C	SC	L		

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Stratum A SCS soil type	Stratum A soil dry bulk density, ρ_b^A	Stratum A soil total porosity, n^A	Stratum A soil water-filled porosity, θ_w^A	Stratum B SCS soil type	Stratum B soil dry bulk density, ρ_b^B	Stratum B soil total porosity, n^B	Stratum B soil water-filled porosity, θ_w^B	Stratum C SCS soil type	Stratum C soil dry bulk density, ρ_b^C	Stratum C soil total porosity, n^C	Stratum C soil water-filled porosity, θ_w^C
Lookup Soil Parameters	(g/cm^3)	(unitless)	(cm^3/cm^3)	Lookup Soil Parameters	(g/cm^3)	(unitless)	(cm^3/cm^3)	Lookup Soil Parameters	(g/cm^3)	(unitless)	(cm^3/cm^3)
L	1.40	0.399	0.148	L	1.4	0.399	0.148	SC	1.3	0.385	0.197

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Enclosed space floor thickness, L_{crack}	Soil-bldg. pressure differential, ΔP	Enclosed space floor length, L_B	Enclosed space floor width, W_B	Enclosed space height, H_B	Floor-wall seam crack width, w	Indoor air exchange rate, ER	Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil}
(cm)	(g/cm-s^2)	(cm)	(cm)	(cm)	(cm)	(1/h)	(L/m)
10	40	1000	1000	366	0.1	0.25	5

MORE ↓

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Averaging time for carcinogens, AT_C	Averaging time for noncarcinogens, AT_{NC}	Exposure duration, ED	Exposure frequency, EF	Target risk for carcinogens, TR	Target hazard quotient for noncarcinogens, THQ
(yrs)	(yrs)	(yrs)	(days/yr)	(unitless)	(unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based groundwater concentration.

END

APPENDIX E

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Evaluation of the Johnson and Ettinger Model for Prediction of Indoor Air Quality

by Ian Hers, Reidar Zapf-Gilje, Paul C. Johnson, and Loretta Li

Abstract

Screening level models are now commonly used to estimate vapor intrusion for subsurface volatile organic compounds (VOCs). Significant uncertainty is associated with processes and models and, to date, there has been only limited field-based evaluation of models for this pathway. To address these limitations, a comprehensive evaluation of the Johnson and Ettinger (J&E) model is provided through sensitivity analysis, comparisons of model-predicted to measured vapor intrusion for 11 petroleum hydrocarbon and chlorinated solvent sites, and review of radon and flux chamber studies. Significant intrusion was measured at five of 12 sites with measured vapor attenuation ratios (α_m's) (indoor air/source vapor) ranging from ~1 $\times$ 10^{-6} to 1 $\times$ 10^{-4}. Higher attenuation ratios were measured for studies using radon, inert tracers, and flux chambers; however, these ratios are conservative owing to boundary conditions and tracer properties that are different than those at most VOC-contaminated sites. Reasonable predictions were obtained using the J&E model with comparisons indicating that model-predicted vapor attenuation ratios (α_p's) were on the same order, or less than the α_m's. For several sites, the α_m were approximately two orders of magnitude less than the α_p's indicating that the J&E model is conservative in these cases. The model comparisons highlight the importance in using appropriate input parameters for the J&E model. The regulatory implications associated with use of the J&E model to derive screening criteria are also discussed.

Introduction

The use of models to predict indoor air quality associated with volatile organic compound (VOC) contamination in soil and ground water is now commonplace (ASTM 1995; Johnson et al. 1998, Hers et al. 2002). Screening models typically used for this pathway are the Johnson and Ettinger (1991) model (henceforth referred to as the J&E model), or variants thereof. Processes controlling the intrusion of VOC vapors into buildings are not well understood, the accuracy of the J&E model is uncertain, and there have been only limited comparisons of model predictions to field data. There are also substantial differences in the way in which the J&E model is used for regulatory purposes.

To address these limitations, this paper presents a comprehensive evaluation of the J&E model based on theoretical considerations and field data from petroleum hydrocarbon and chlorinated solvent sites, and radon and flux chamber studies. Data sources are published studies, consultant or agency reports, and a field-based research program conducted by the authors. Included in the data sets analyzed are several recent groundbreaking investigations at chlorinated solvent sites.

The paper begins with an analysis of methods for estimating input parameters for the J&E model and their effect on model sensitivity and uncertainty. This analysis provides the needed context for the methods employed to interpret the field data used for this study. It is also important because it is essential that model attributes and potential limitations be understood before using field data to evaluate the predictive capabilities of a model. Field-based methods for the evaluation of vapor attenuation ratio (α), defined as the indoor air concentration divided by the source vapor concentration, are evaluated next. The primary focus is measured vapor attenuation ratios (α_m) from 11 sites with petroleum hydrocarbon and chlorinated solvent contamination. Information from tracer studies using radon or an injected tracer such as sulpher hexafluoride (SF_6), and flux chamber studies are also reviewed. The measured α_m from field studies are compared to model-predicted vapor attenuation ratios (α_p) using the J&E model. Trends in the data are qualitatively evaluated and possible factors affecting vapor intrusion are considered. The paper also comments on the use of the J&E model to derive regulatory screening criteria.

J&E Model Input Parameters, Sensitivity, and Uncertainty

The basic form of the J&E model couples one-dimensional steady-state diffusion through soil, and diffusion and advection through a building envelope (i.e., foundation). A simple "box" model, which assumes uniform and instantaneous mixing of chemicals within the building enclosure, is used to estimate the indoor air concentration. Model sensitivity and uncertainty analysis and input needed for comparisons of
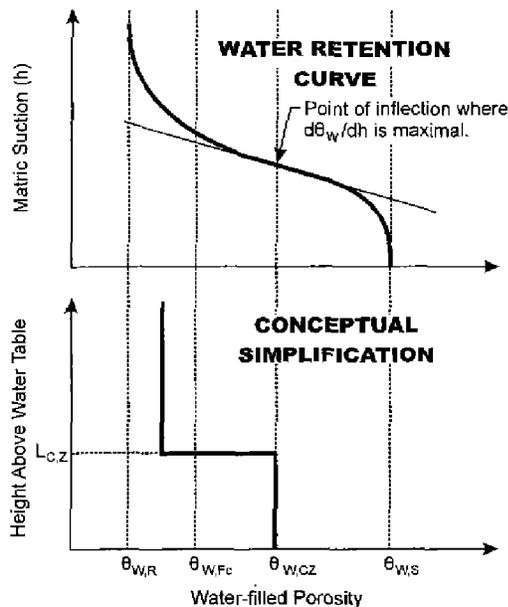
Figure 1. Conceptual simplification of water retention curve for purposes of estimating moisture contents and capillary rise ($\theta_{W,R}$, $\theta_{W,FC}$, $\theta_{W,CZ}$, $\theta_{W,S}$ are the residual, field capacity, capillary zone, and saturated water contents).

model predictions to field data all require estimation of effective diffusion coefficient and soil gas advection rate. Because the available data varied, different methods were used to estimate these input parameters and interpret field data. The estimation methods subsequently used in this paper are discussed in the following sections.

Estimation of Effective Diffusion Coefficient (Air-Filled and Total Porosity)

The J&E model uses the Millington and Quirck (1961) relationship to estimate the effective diffusion coefficient (D_T^{eff}), as follows:

$$D^T_{eff} = (\theta_a^{(10/3)} / \theta^2) * D_{air} + 1/H' * (\theta_w^{(10/3)} / \theta^2) * D_{water}$$

where θ_a, θ_w, and θ are the air-filled, water-filled, and total porosity; D_{air} and D_{water} are free-air and free-water diffusion coefficients (L^2T^{-1}); and H' is the dimensionless Henry's law constant.

A common method for estimating air-filled and total porosity directly uses the measured soil moisture content and bulk density. A potential disadvantage is that soil disturbance during sampling can lead to inaccurate moisture, density, and hence, porosity estimates. Samples obtained adjacent to buildings may not be representative of conditions below buildings owing to the drying of soil that can occur.

A second method involves the use of the van Genuchten (VG) model (van Genuchten 1980) to predict the water retention parameters for U.S. Soil Conservation Service (SCS) soil types, based on VG model curve-fit parameters computed by Schaap and Leij (1998) (Simplified VG method). This method, developed by Environmental Quality Management Inc. (EQM 2000), is incorporated in U.S. EPA guidance for this

pathway. The VG model parameters are, in turn, used to develop a simplified step function for water-filled porosity (Figure 1). The capillary zone ($\theta_{w,cz}$) water-filled porosity is equal to the moisture content at the inflection point in the water retention curve where $d\theta_w/dh$ is maximal, as suggested by Waitz et al. (1996) (where θ_w and h equal the water-filled porosity and matric suction, respectively). Vapor-phase diffusion becomes negligible once the water-filled porosity exceeds the $\theta_{w,cz}$. The height of the capillary zone is estimated using an equation for capillary rise in a tube (Fetter 1994), and mean particle size for the SCS soil textural classifications (Nielson and Rogers 1990). The water-filled porosity above the capillary zone is user defined; we suggest a practical range below a building is between the residual water content and field capacity.

The simplified VG model likely predicts lower than actual water-filled porosity in soil, for the capillary transition zone (Figure 1). Because diffusion rates are much higher in air than water, this simplification likely results in conservative (high) diffusion estimates through the capillary transition zone. However, this conservatism may be counterbalanced by nonrepresentative assumptions for the ground water contamination source. The common paradigm for prediction of cross-media VOC transport is that dissolved chemicals are present below a static water table, and that transport through the capillary transition zone is limited to vapor- and aqueous-phase diffusion. In reality, there will be some lateral ground water flow and dispersive mixing of chemicals in the tension-saturated zone, and vertical movement of chemicals as a result of water-table fluctuations. There is limited information on VOC migration in the capillary transition zone. One study, involving a large chamber, showed that the pore-water concentrations in the tension-saturated zone were similar to those below the water table, and showed a sharp decline in concentrations near the top of the tension-saturated zone (McCarthy and Johnson 1993). The implication is that a more representative top boundary for dissolved ground water contaminants may be some distance above the water table.

Estimation of Soil Gas Advection Rate (Q_{soil})

The method often used with the J&E model for estimating the soil gas advection rate (Q_{soil}) through the building envelope is an analytical solution for two-dimensional soil gas flow to a small horizontal drain (Nazaroff 1992). This model is used to simulate gas flow to an edge crack located at the perimeter of a building (perimeter crack model). The Q_{soil} (L^3T^{-1}) is estimated as follows:

$$Q_{soil} = \frac{2 \pi k_a \Delta P X_{crack}}{\mu \ln\left(\frac{2 z_{crack}}{r_{crack}}\right)} \qquad (2)$$

where k_a is the soil-air permeability (L^2), ΔP is the pressure difference between the building and ambient air, X_{crack} is the perimeter crack length (L), μ is the gas viscosity ($ML^{-1}T^{-1}$), z_{crack} is the depth to edge crack (L), and r_{crack} is the crack radius (L). The ratio of cracks to total subsurface foundation area (i.e., base and walls) (η) can be expressed as

Figure 3. Sensitivity of vapor attenuation ratio (benzene) to soil-gas flow rate (Q) into building using perimeter crack model with dry dust-filled concrete cracks with total porosity = 0.3 Height = building height, $Q = Q_{soil}$ ACH = air exchanges per hour (other symbols previously defined).

Figure 2. Sensitivity of soil gas flow to perimeter crack model (used in J&E model) to (a) soil-air permeability (k_a), (b) depth to perimeter crack (z_{crack}), and (c) crack ratio (η). X_{crack} = perimeter crack length, A_b = subsurface foundation area.

$$\eta = \frac{r_{crack} X_{crack}}{A_B} \qquad (3)$$

where A_B is the subsurface foundation area (L^2). The perimeter crack model accounts for both soil gas flow through soil and the foundation, but is most sensitive to the soil-air permeability based on the analysis presented in Figure 2. For the range of values chosen for k_a, η, ΔP, and z_{crack}, by far the greatest variation is obtained for k_a with the predicted Q_{soil} ranging between ~0.001 and 100 L/min.

One method of estimating soil-air permeability is to use published values for saturated hydraulic conductivity and water retention parameters for a particular soil type (EQM 2000). This method involves the following steps: (1) obtain saturated hydraulic conductivity for soil texture type (Schaap and Leij 1998); (2) estimate intrinsic permeability from saturated hydraulic conductivity; (3) estimate effective total fluid saturation at field capacity;

(4) estimate relative air permeability using the relationship proposed by Parker et al. (1987); and (5) calculate effective soil-air permeability (relative air permeability multiplied by intrinsic permeability). The soil-air permeability can also be measured in the field (Garbesi and Sextro 1995; Hers and Zapf-Gilje 1998); however, this type of testing is rarely performed.

The Q_{soil} can also be estimated from a tracer test mass balance. When soil-gas advection is the primary mechanism for tracer intrusion into a building, the Q_{soil} can be estimated by measuring the concentrations of a chemical tracer in indoor air, outdoor air, and in soil vapor below a building, and measuring the building ventilation rate (Hers et al. 2002; Fischer et al. 1996; Garbesi et al. 1993; Rezvan et al. 1991; Garbesi and Sextro, 1989). The Q_{soil} values measured using this technique are compared to predicted rates using the perimeter crack model, for sites with coarse-grained soils (Table 1). The perimeter crack model predictions are both higher and lower than the measured values, but overall are within one order of magnitude of the measured values. Although the Q_{soil} predicted by models and measured using field tracer tests are uncertain, the results suggest that a "typical" range for houses on coarse-grained soils is on the order of 1 to 10 L/min.

J&E Model Sensitivity for Key Input Parameters

The sensitivity of the benzene α_p predicted by the J&E model is evaluated as a function of soil gas flow (Q_{soil}), the effective diffusion coefficient (D_T^{eff}), and contamination depth (L_T) (Figure 3). The D_T^{eff}/L_T ratio captures the influence of soil properties and depth to contamination source on α_p. For BTEX and most chlorinated solvent compounds, chemical-specific variation in the D_T^{eff}/L_T ratio is not significant because the free-air diffusion coefficients vary by only a factor of two, and the Henry's law constants vary by a factor of 10 $(D_T^{eff}/L_T$ is less sensitive to H' than $D_{air})$. Because the effective diffusion coefficient is calculated using the Millington and Quirck (1961) relationship, the soil properties of relevance are the air-filled and total porosity. A high D_T^{eff}/L_T ratio is asso-

Table 1
Comparison of Measured and Model-Predicted Soil Gas Flow Rates Into Buildings

Site	Foundation Type	ΔP (Pa)	Subsurface Foundation Area (m²)	Crack Ratio η	Depth to Perimeter Crack (m)	$k_{soil-air}$ (Darcy)	Soil Gas Flow Rates Measured Tracer (L/min)	Soil Gas Flow Rates Predicted PCM (L/min)
Chatterton Site (Hers et al. 2000)	Slab-on-grade	30	57	0.00033	0.3	10	2.7	29
	Slab-on-grade	10	57	0.00033	0.3	10	4.2	9.6
	Slab-on-grade	10	57	0.0001	0.3	10	2.9	8.2
Alameda Site Fischer et al. (1996)	Slab-on-grade	3	50	**0.0001**	0.2	10	1.4	2.4
Central California Site Garbese & Sextro (1989)	Filled hollow block basement w/coating	30	128	**0.0001**	2.5	3	67	8.3
Ben Lomond Garbesi et al. (1993)	Experimental basement	10	26	0.00075	1.8	6	9.7	2.3
Spokane Valley Houses Revzan et al. (1991)	Poured concrete basements	5	220	0.0001	2	200	102	110

Notes: Bold print values assumed, all other values measured, ΔP = building underpressurization, PCM = Perimeter Crack model.

Table 2
Qualitative Summary of Sensitive Parameters for the J&E Model

	Building Depressurized (Advection and Diffusion)	Building Not Depressurized (Diffusion Only)
High D_T^{eff}/L_T (shallow and/or dry soil)	Q_{soil} (advection controlled)	Building foundation cracks
Moderate D_T^{eff}/L_T	Q_{soil} and moisture content (MC)	Building foundation cracks and MC
Low D_T^{eff}/L_T (deep and/or wet soil)	Moisture content (diffusion controlled)	Moisture content (MC)

Note: Indoor air concentrations are directly proportional to source concentrations, building mixing height and ventilation rate.
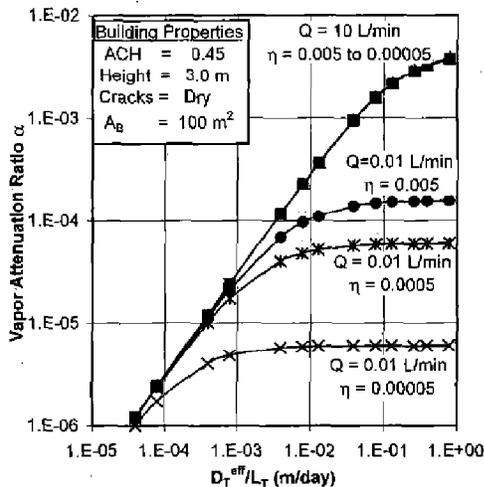
Figure 4. Sensitivity of vapor attenuation ratio (benzene) to soil-gas flow rate (Q) using perimeter crack model and foundation crack ratio (η) (other symbols previously defined).

ciated with dry soils and/or shallow contamination, whereas a low D_T^{eff}/L_T ratio is associated with wet soils and/or deep contamination. Based on the analysis in the sections that follow, sensitive parameters for the J&E model are also qualitatively summarized in Table 2.

Sensitivity of α_p to Q_{soil}

For sensitivity analysis purposes, a Q_{soil} range of 0.01 to 10 L/min was chosen because it is considered representative of most houses or small buildings. The results indicate that Q_{soil} begins to have a significant influence on α_p when D_T^{eff}/L_T values are moderate to relatively large (>~0.001 m/day) (Figure 3). The J&E model is described to be advection controlled for this scenario. When D_T^{eff}/L_T is relatively small (<~0.001 m/day), α_p is not sensitive to Q_{soil}. The J&E model is described to be diffusion controlled for this scenario. The D_T^{eff}/L_T for case studies subsequently evaluated in this paper ranged from ~0.002 to 0.1 m/day. For these D_T^{eff}/L_T values, the maximum error in prediction caused by a four order of magnitude variation in Q_{soil} ranges from 3X to 100X.

Sensitivity of α_p to Crack Ratio

The influence of crack ratio (η) on α_p was evaluated for two different Q_{soil} values (Figure 4). For Q_{soil} = 10 L/min, α_p is not sensitive to η. When Q_{soil} = 0.01 L/min, a two order of magnitude change in η causes up to 25X change in α_p. The sensitivity of α_p to η increases as Q_{soil} decreases, with sensitivity highest for the diffusion-only case (i.e., Q_{soil} = 0). The crack ratio is of little importance for smaller D_T^{eff}/L_T or Q_{soil} >~1 L/min, which means that for the majority of sites crack ratio will not be important.
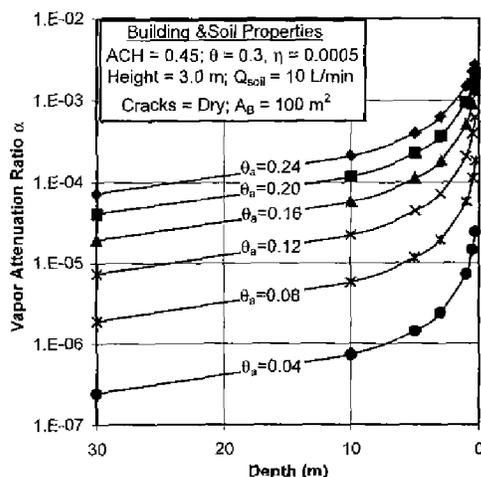
Figure 5. Sensitivity of vapor attenuation ratio (benzene) to water–filled porosity (θa). Other symbols previously defined.

Sensitivity of α_p to Air-Filled Porosity (Moisture Content)

The effect of air-filled porosity and depth to contamination was evaluated for a soil with moisture contents ranging from 3.6% to 15.6% (dry weight) and a constant total porosity of 0.3 (Figure 5). This variation in moisture content is potentially representative of the difference between a dry soil below a building compared to a wet soil within the capillary transition zone. The corresponding air-filled porosities are between 0.04 and 0.26. A Q_{soil} value of 10 L/min was assumed. For a constant depth to contamination, a 4X change in moisture content causes approximately or more than two orders of magnitude change in α_p. For a constant moisture content, α_p becomes sensitive to depth to contamination, at shallow depths. It is clear that soil layers with high moisture content will have a significant effect on the diffusive flux and vapor intrusion.

J&E Model Uncertainty for Range of Values

Vapor attenuation ratios predicted by the J&E model are provided for a range of soil gas advection rates and building properties, as a function of D_T^{eff}/L_T (Figure 6). For illustrative purposes, upper and lower soil-gas advection rates were estimated for four U.S. SCS soil textures (sand, loamy sand, sandy loam, and silt) using published values for saturated hydraulic conductivity and the perimeter crack model. The soil type only applies to soil immediately adjacent to the building, because the radius-of-influence for soil-gas advection is relatively limited. The estimated Q_{soil} values are highly uncertain; however, we note that the predicted values for sand (1 to 10 L/min) are consistent with the results of tracer tests for coarse-grained soils. The uncertainty in Q_{soil} increases for finer-grained soils because the influence of permeable soil layers and preferential pathways (e.g., utility backfill) becomes more important. It is suggested that the Q_{soil} for sand be used when near the foundation soil is not well characterized.

The building properties input to the model are the crack ratio, dust-filled crack moisture content, building height, building air exchanges, and building foundation size. The upper and lower building properties given are subjectively considered to represent the range of values that would be encountered at most

sites, based on available information and the author's experience (Hers and Zapf-Gilje 1998; Hers et al. 2001). The subsurface foundation area is for a house with a shallow basement or slab-on-grade foundation. Slightly lower α_p's would be predicted for a deep basement with larger foundation area.

The graphs in Figure 6 illustrate the effect of variation in Q_{soil} and building properties on vapor attenuation ratio, but do not address uncertainty in D_T^{eff}/L_T, which is primarily caused by soil moisture content. To gain insight into uncertainty in model predictions owing to moisture content, a possible range in D_T^{eff}/L_T was evaluated for two hypothetical scenarios. The first scenario (Site 1) assumes a shallow soil vapor source (1.5 m depth) situated well above the water table. The second scenario (Site 2) assumes a relatively deep water table (6 m depth) and contamination that is limited to a dissolved ground water plume. Both sites were assumed to have uniform SCS loamy sand soil. The approach taken was to first obtain a plausible best estimate, and upper and lower range for D_T^{eff}/L_T. For Site 1, a constant air-filled porosity halfway between the residual water content and field capacity was assumed. For Site 2, the simplified VG method was used to estimate the air-filled and total porosity for the capillary zone. As shown in Table 3, the resulting porosities are expressed as relative water saturation values where $S = \theta_w/\theta$ and $\theta_a = \theta$ (1-S). The reason for using relative saturation values in the uncertainty analysis is that the air-filled and total porosity are expected to be strongly correlated. Therefore, uncertainty would be overestimated if these parameters are allowed to vary independently. This is prevented through the use of the relative saturation values. The uncertainty ranges given for total porosity and relative saturation are considered reasonable values for a well-characterized site.

Using the best estimate values and uncertainty ranges, the best estimate, lower and upper ranges are provided for the normalized effective diffusion coefficient (D_T^{eff}/L_T) (Table 3 and Figure 6). For Site 1, the upper and lower D_T^{eff}/L_T values vary by a factor of 2.4. For Site 2, the uncertainty is greater (factor of 23) because the sensitivity of D_T^{eff}/L_T to air-filled porosity within the capillary zone is high because moisture content is also high.

The overall uncertainty in the vapor attenuation ratio will be dependent on the available data. If there is information only on the contamination depth, the range in α_p can vary three to four orders of magnitude. When information on soil properties is also available, the uncertainty in D_T^{eff}/L_T and Q_{soil} is reduced resulting in α_p that vary over two orders of magnitude (Figure 6). When good quality site-specific data is available for both soil properties (e.g., moisture content) and building properties (e.g., ventilation rate, mixing height), it may be possible to reduce the uncertainty in α_p to approximately one order of magnitude.

Field–Based Methods for Evaluation of Vapor Intrusion

Three field-based approaches or methods are used to evaluate vapor intrusion: the indoor VOC method, the tracer method, and the flux chamber method. The *indoor VOC method* involves measurement of VOC concentrations in indoor air and at the contamination source. The α_m will vary depending on the contamination scenario. For sites with dissolved ground water plumes, the α_m is calculated using a
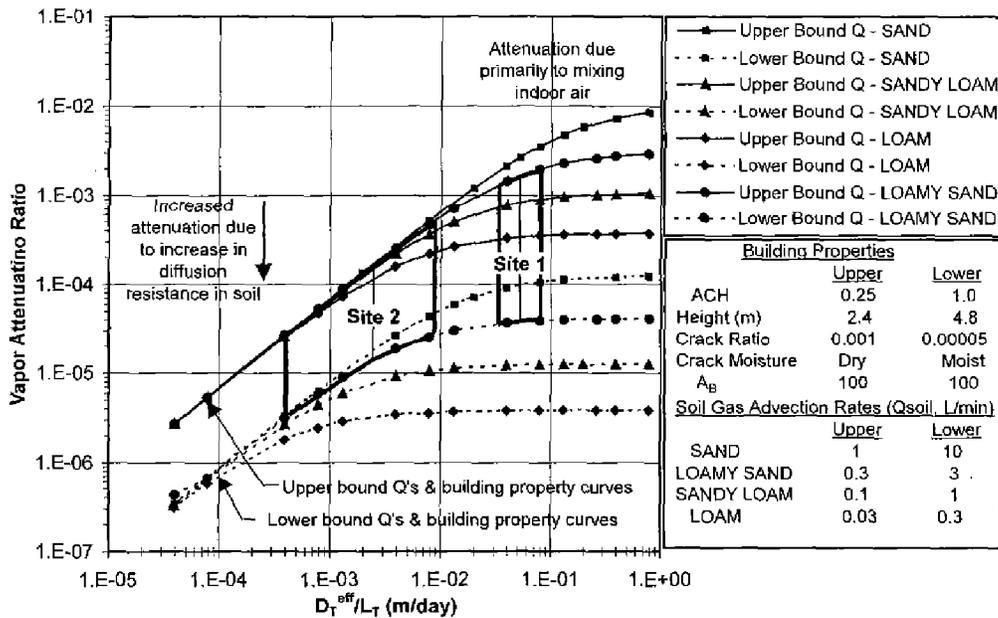
Figure 6. Predicted vapor attenuation ratio (benzene) for vapor concentrations at source and indoor air using Johnson and Ettinger (1991) model. Figure adapted from Johnson et al. (1998). Dry dust-filled cracks: Total porosity = 0.3; moist dust-filled cracks: water-filled porosity = 0.1, and total porosity = 0.3.

Table 3
Uncertainty Analysis for Normalized Effective Diffusion Coefficient

Parameters	Best Estimate Values		Uncertainty
	Site 1	Site 2	
Input Parameters			
Contamination	Above WT	Dissolved in Gdw	N/A
Contamination depth (m)	1.5	6.0	constant
U.S. SCS soil classification	Sandy Loam	Sandy Loam	N/A
Total porosity (θ)	0.390	0.390	+/- 10%
S_R (θ_w/θ) above CZ (S)	0.265	0.265	+/- 25%
Height of CZ (L_{cz}) (m)	N/A	0.250	+/- 25%
S_R (θ_w/θ) in CZ (S_{cz})	N/A	0.821	+12/-10%
Calculated Values			
D_T^{eff}/L_T lower est. (m/day)	0.0325	0.00038	
D_T^{eff}/L_T best est. (m/day)	0.0512	0.00248	
D_T^{eff}/L_T lowest est. (m/day)	0.0775	0.00861	
D_T^{eff}/L_T upper/lower range	2.4	23	

Notes: CZ = capillary zone, S_r = relative saturation, Gdw = Ground water, WT = water table.

predicted source vapor concentration (i.e., directly above the water table) estimated using the Henry's law constant assuming equilibrium partitioning between the dissolved and vapor phases. When measured source vapor concentrations are available, the α can be directly calculated. Because some deviation from equilibrium conditions would be expected, the α_m estimated using ground water and soil vapor data are not directly comparable. A key challenge for this approach is that there are numerous other "background" sources of VOCs in indoor and outdoor air for most chemicals of concern at contaminated

sites (Hers et al. 2001). The intrusion of soil vapor into buildings is also highly dependent on site-specific conditions and may vary over time. These factors complicate the interpretation of indoor air measurements when the goal is to deduce the subsurface-derived component.

The *tracer method* involves measurement of the indoor air concentration of a tracer injected below ground (SF_6), or a natural tracer such as radon (Fisher et al. 1996; Garbesi et al. 1993). The measured vapor intrusion for the tracer is, in turn, used to infer intrusion for the VOC of interest. Key factors affecting this approach are that boundary conditions for a tracer injected below a building may be different than those for the VOC of interest (e.g., if contamination is relatively deep) and that typically, an essentially inert tracer is used. When compared to the tracer, the mass loss or attenuation through sorption and/or biodegradation will be greater for most VOCs of interest. For these reasons, the tracer method will typically provide a conservative estimate of intrusion.

The *flux chamber* method involves measurement of soil-gas flow and/or VOC flux through cracks or openings in a building foundation. There are only a few published reports documenting the use of flux chambers to measure VOC flux into buildings (Figley and Snodgrass 1992; Hers and Zapf-Gilje 1998). Challenges for this approach are that these tests are difficult and costly to perform, and the uncertainty associated with "scaling up" the results for a small crack to an entire building.

Results and Discussion of Field Studies and Model Predictions

Indoor VOC Method

Vapor attenuation ratios are evaluated for 11 sites. The sites represent studies available to the authors with reasonable quality field data, and are for residential houses, ground-floor

Table 4
Measured and Model-Predicted Vapour Attenuation Ratios

Site & Reference	Contaminant or Tracer	Building and Foundation Type	Soil Conditions	Depth (m)[1]	Chemical	Source Concentration (ug/L)	N Indoor Air[2]	α_m Statistic	Measured α_m	J&E model α_p[3]	Comments
Indoor VOC Method											
"Virginia (Motiva) Site", Fan and Quinn (2000)	petroleum HC, NAPL above water	SFR, basements, attached garages, cement block foundations k ~ 0.01 darcy	claystone saprolite	0.5	benzene	V: 410	13	50th	<8.3E-6	3.70E-06	
"Chatterton Site" Delta, B.C. Canada Hers et al. (1998) Hers et al.(2000a)	BTX petrochemical plant, NAPL above water table	research greenhouse slab-on-grade poured concrete 2 mm edge crack	surface silt to f. sand, underlain by m.sand with k ~ 10 darcies	1.4	benzene	V: 15,000	3-4	Avg	<5.3E-7	1.3E-05	C1: ΔP= 0 Pa, η = 3.3E-4
					toluene	V: 20,000	3-4	Avg	< 1.9E-6	1.3E-05	C1: ΔP= 0 Pa, η = 3.3E-4
					benzene	V: 15,000	3-4	Avg	4.0E-07	5.9E-05	C2: ΔP= 2.5 Pa, η = 1E-4
					toluene	V: 20,000	3-4	Avg	5.9E-07	5.9E-05	C2: ΔP= 2.5 Pa, η = 1E-4
					benzene	V: 15,000	3-4	Avg	9.9E-05	7.8E-05	C3: ΔP= 10 Pa, η = 1E-4
					toluene	V: 20,000	3-4	Avg	1.3E-04	7.8E-05	C3: ΔP= 10 Pa, η = 1E-4
					benzene	V: 15,000	3-4	Avg	7.2E-06	8.0E-05	C4: ΔP= 10 Pa, η = 3.3E-4
					toluene	V: 20,000	3-4	Avg	3.4E-05	8.0E-05	C4: ΔP= 10 Pa, η = 3.3E-4
					benzene	V: 15,000	3-4	Avg	5.8E-06	2.9E-05	C5: ΔP= 30 Pa, η = 3.3E-4
					toluene	V: 20,000	3-4	Avg	2.2E-05	2.9E-05	C5: ΔP= 30 Pa, η = 3.3E-4
"Paulsboro Site", NJ USA, Laubacher et al. (1997)	gasoline NAPL above water table	SFR basement	sand, some silt	2.74	benzene	V: 576	15	Avg	<1.6E-6	4.3E-04	
"Alameda (Air Station) Site", CA, USA Fischer et al.(1996)	gasoline NAPL above water table	small commercial building, slab-on-grade poured concrete	sand k ~ 1 to 3 darcy	0.7 0.7	benzene iso-pentene	V: 200 V: 28,000	1 1	N/A N/A	<9E-6 < 9E-7	2.45E-04 2.46E-04	
"Mass. DEP Sites" USA, Fitzpatrick & Fitzgerald (1996)	petroleum hydrocarbon	N/A (3 sites)	N/A	N/A	benzene	N/A	-	N/A	1E-5 to 4E-5	INS INS	
"Midwest School Site" USA, Moseley and Meyer (1992)	petroleum HC NAPL above water table	Built 50's, at-grade construction, crawlspace, large paved area	sand & gravel, discontinuous clay lenses	~ 3	benzene total HC	N/A	N/A	N/A	HC-like odours -- 1E-4	INS	crawlspace conc.: benzene – 8.3 mg/m³, Total HC ~ 500 mg/m³
"CDOT HDQ Site" Colorado, USA Johnson et al. (2000)	chlorinated solvents, dissolved plume	mostly apartments, few SFRs, mostly slab-on-grade, few crawlspaces & basements, AC mostly window units, heating natural gas, baseboard, and/or fireplaces	weathered & fractured claystone above water table	4.6	1,1 DCE	G: 10-10,000	115-	Geom	4.8E-06		α_m values for houses above plume with DCE groundwater concentration > 10 ug/L
					1,1 DCE	G: 10-10,000	150	90th	2.0E-05		
					TCE	G: 3-3,000	115-	Geom	1.4E-05		
					TCE	G: 3-3,000	150	90th	7.0E-05		
					1,1,1 TCA	G: 10-1,000	115-	Geom	1.7E-05		
					1,1,1 TCA	G: 10-1,000	150	90th	6.6E-05		
					above 3 CS		115-	Geom	1.2E-05	8.6E-05	average for 3 chlorinated
					above 3 CS		150	90th	5.2E-05	2.4E-04[4]	solvents (CS)
"Redfields Site" Colorado, USA Envirogroup (1999)	chlorinated solvents, dissolved plume	SFRs, built 50's and 60's, mostly basements or crawlspaces, no combustion air intakes	clay & silt, some sand layers, mostly sand or silt near WT	6.1 to 7.3	1,1 DCE	G: 10-1,000	65	50th	1.50E-05	INS	α_m values for houses above plume with DCE groundwater concentration > 10 ug/L
					1,1 DCE	G: 10-1,000	65	Avg	7.60E-05		
					1,1 DCE	G: 10-1,000	65	90th	1.20E-04		
Hamilton Site Colorado, USA (2001), unpublished	chlorinated solvents, dissolved plume	SFRs built 50's most basements	primarily sand & & gravel, some clay & silt layers	9.7 to 11	1,1 DCE	G: 15-30 G: 15-30	32 32	50th 90th	6.80E-05 1.40E-04	INS	Gravel at water table
"Lowry (Air Force Base) Site" Colorado, USA Versar (2000)	chlorinated solvents, dissolved	SFR: mostly basements some crawlspaces	silty sand to silt, generally silty sand near water table	6.1 to 7	1,1 DCE	G: 1.4-1.9	>50	50th	2.20E-05	INS	max G α_m = 6.2E-04
					TCE	G: 120-170	>50	50th	2.20E-05		max G α_m = 1.2E-03
					1,1 DCE	V: >29	>50	50th	6.50E-04		max V$_{SS}$ α_m = 8.3E-03
					TCE	V: >1,000	>50	50th	7.70E-04		max V$_{SS}$ α_m = 1.4E-02
"Mountain View Site" California, USA Wu (2000)	chlorinated solvents, leachfield & dissolved[5]	SFRs, built 1998, at-grade construction with moisture vapor barrier	mostly silty/ clayey sand & gravel, some sand or silt lenses	1.5 10.7	TCE TCE	V: 84 V: 84 G: 735 G: 735	14 14 14 14	Max 2nd[6] Max 2nd	2.80E-04 <1.3E-5 7.80E-05 <3.6E-5	INS	α_m shallow vapour α_m groundwater, depth to groundwater = 10.7 m
"Mass. DEP Sites" USA, Fitzpatrick & Fitzgerald (1996)	chlorinated solvents	N/A (19 sites)	N/A	N/A	CS	N/A	N/A	N/A	2E-6 to to 1E-1	INS	high α_m associated with highly permeable building envelopes (earthern floor, block walls & sumps)
Tracer and Flux Chamber Tests											
"Central California Site", Garbesi & Sextro (1989)	SF₆	SFR, basement poured slab, block walls coated with asphalt	sandy loam to loamy sand, k = 0.1 to 10 darcies	sub-slab	SF₆	N/A	N/A	N/A	~ 1E-3	N/A	ΔP = 30 Pa
"Alameda Site" Fischer et al. (1996)	SF₆	small commercial, slab on-grade, concrete	sand, k = 1 to 3 darcy	sub-slab	SF₆	N/A	N/A	N/A	2E-4 to 4E-4	N/A	ΔP ~ 3 (estimate based on wind loading)
U.S. Sites Little et al.(1992)	radon	SFRs	N/A	sub-slab	radon	N/A	N/A	N/A	1.6E-3[7]	N/A	
"Spokane River Valley Sites", WA, USA, Rezvan et al. (1992)	radon	SFRs (14), 8 houses slab-on-grade, 6 basement	highly permeable sand & gravel, k ~ 200 darcies	sub-slab	radon	N/A	N/A	N/A	~ 7.9E-3 to to 4.5E-2	N/A	winter conditions, mean house volume ≈ 500 m³, ACH = 0.5/hr

Notes: [1]Depth to contamination from underside of foundation slab; [2]N = Number of indoor air samples tested; [3]Best estimate unless otherwise noted; [4]Upper range; [5]Contamination likely in unsaturated zone; [6]2nd highest α_m value; [7]Alpha (α) estimated using mean radon content of soil combined with appropriate constant divided by radon concentration in U.S. homes (55 Bq m-3); [6]N/A = not available or applicable, SFR = single family residence, SF₆ = sulpher hexafluoride; V = vapor, V$_{ss}$ = sub-slab, G = ground water, bgs = below ground surface, HC = hydrocarbon, AC = air-conditioning, INS = insufficient data, ACH = air exchanges per hour, WT = water table, CS = chlorinated solvents.

Table 5
Input Parameter Values Used for Johnson and Ettinger (1991) Model[1]

Parameter	Virginia Site	Chatterton Site	Paulsboro Site	Alameda Site	Midwest Site	CDOT HDQ Site	Redfields Site	Hamilton Site	Lowry Site	Mountain West Site
US SCS soil type used for D_T^{eff}/L_T	N/A	N/A	N/A	N/A	N/A	N/A	Loamy Sand	Sand	Loamy Sand	N/A
Depth to contamination (L_T) (m)	0.5	1.4	2.74	0.7	3.0	4.8	6.1	10.3	0.25[1]	1.5[2]
									6.1[3]	10.7[3]
Total porosity unsaturated zone (θ)	0.43	0.36	0.39	0.36	0.4	0.4	0.39	0.375	0.39	0.41
Air-filled θ unsaturated zone (θ_a)	0.28	0.21	0.23	0.22	0.25	0.26	0.287	0.319	0.287	0.2
Height of capillary zone (L_c) (m)	N/A	N/A	N/A	N/A	N/A	0.2	0.25		0.17	0.25
Total θ capillary zone (θ_c)	N/A	N/A	N/A	N/A	N/A	0.4	0.39	0.375	0.39	0.41
Air-filled θ capillary zone ($\theta_{a,c}$)	N/A	N/A	N/A	N/A	N/A	0.08	0.07	0.12	0.07	0.1
D_T^{eff}/L_T (m/day)	0.12[4]	0.023[4]	0.014[4]	0.054[4]	0.016[4]	3.4E-3[6]	2.4E-3[7]	8.4E-3[7]	0.49[8]	0.013[10]
				0.050[5]					2.4E-3[9]	1.5E-3[11]
Soil-air permeability k_a (10^{-12} m²)	0.01	10	10	3	—	N/A[12]	—	—	—	—
Building underpressurization (Pa)	1	0, 2.5, 10, 30	5	3	—	N/A[12]	—	—	—	—
Foundation crack ratio (η)	1.5E-03	3.3E-4 to 1E-4	1.E-04	1.E-04	—	1.E-04	—	—	—	—
x_{crack} (m)	55.9	26.8	27.6	26.8	—	N/A[12]	—	—	—	—
z_{crack} (m)	2.0	0.3	2.13	0.2	—	N/A[12]	—	—	—	—
Q_{soil} (L/min)	0.0016	8.2 to 29	2.8	2.2	—	10	—	—	—	—
Total θ dust-filled cracks (θ_{crack})	0.43	0.25	0.25	0.25	—	0.4	—	—	—	—
Air-filled θ dust-filled cracks ($\theta_{a,crack}$)	0.28	0.25	0.25	0.25	—	0.26	—	—	—	—
Air exchange per hour (ACH)	0.76	0.42 to 14.3	0.42	2.1	—	0.45	—	—	—	—
Building mixing height (m)	2.0	2.19	2.74	2.4	—	3.0	—	—	—	—
Subsurface building area (A_B) (m²)	186	57	39	50	—	89	—	—	—	—

Notes: [1]Depth to sub-slab soil gas probes; [2]Depth to shallow gas probes; [3]Depth to ground water; [4]Benzene; [5]Iso-pentene; [6]Average 1, 1 DCE, TCE and 1,1,1 TCA; [7]1,1,DCE; [8]DCE for sub-slab vapor source (TCE value is 0.43); [9]DCE for ground water source (value for TCE is 2.2E-03); [10]TCE for shallow vapor source; [11]TCE for ground water source; [12]Q_{soil} is etimated directly; therefore x_{crack}, z_{crack}, ΔP and k_a not needed; [13]Building foundation thickness not included since has negligible effect.

apartments, or small commercial buildings. Site characteristics and estimated input parameters are summarized, and measured and J&E model-predicted vapor attenuation ratios (α_m and α_p) are compared (Tables 4 and 5, Figure 7). In most cases, the vapor attenuation ratios are estimated by the authors using site data; in a few cases, the ratios given in references cited in Table 4 are reported. This has led to differences in the statistical estimators used to characterize the variability in α_m and α_p. For completeness, the vapor attenuation ratios reported for several Massachusetts sites are also included in Table 4; these sites are not included in the 11 case study sites discussed later.

The quality and quantity of site characterization data, and ability to distinguish measured indoor air concentrations from background VOC sources varies from site to site. For three sites, the VOC concentrations in a relatively large number of houses above the contaminant plume were significantly greater than house concentrations in background areas, resulting in fairly reliable α_m estimates. For the remaining sites, either the vapor-derived VOC concentrations in indoor air were significant in only a small subset of houses above the contaminant plume, or there was no significant difference between above plume and background indoor air concentrations. The vapor attenuation ratio is not measurable when there is no significant vapor-derived component; however, the indoor air concentrations can be used to calculate upper bound α_m values, represented as "less than" values in Table 4, and dashed lines in Figure 7.

For each site (except Chatterton), a predictive "envelope" for

α_p was generated. A best estimate D_T^{eff}/L_T was directly calculated when reasonably good quality moisture content data was available. When good quality data was not available, the U.S. SCS soil texture class was inferred based on soil descriptions and the simplified VG method was used to calculate D_T^{eff}/L_T. We recognize that inference of soil texture is approximate and subjective. The upper and lower bound D_T^{eff}/L_T values were approximated using the same variability calculated for the two hypothetical sites discussed earlier (Table 3). The upper and lower bounds for Q_{soil} and building properties are the curves presented in Figure 6. A Q_{soil} range of 1 to 10 L/min (i.e., representative of sand) was assumed for all sites (except Virginia) because either coarse soils were present below building foundations, or there was no information on soil type (in these cases, sand was assumed to be present below foundations). Based on the fine-grained near-foundation soils at the Virginia site, a Q_{soil} range of 0.03 to 0.3 L/min (i.e., representative of loam) was assumed. When there was sufficient information on building properties and soil gas advection potential, the J&E model-predicted α_p was also estimated (represented as symbols in Figure 7). For the Chatterton site, only the best estimate α_p were plotted because testing at this site involved an experimental building and test cases not representative of generalized predictive envelopes in Figure 6.

Measured Vapor Attenuation Ratios at Petroleum Hydrocarbon Sites

Case study sites with petroleum hydrocarbon contamination have coarse-grained soils (except for the Virgina site) and
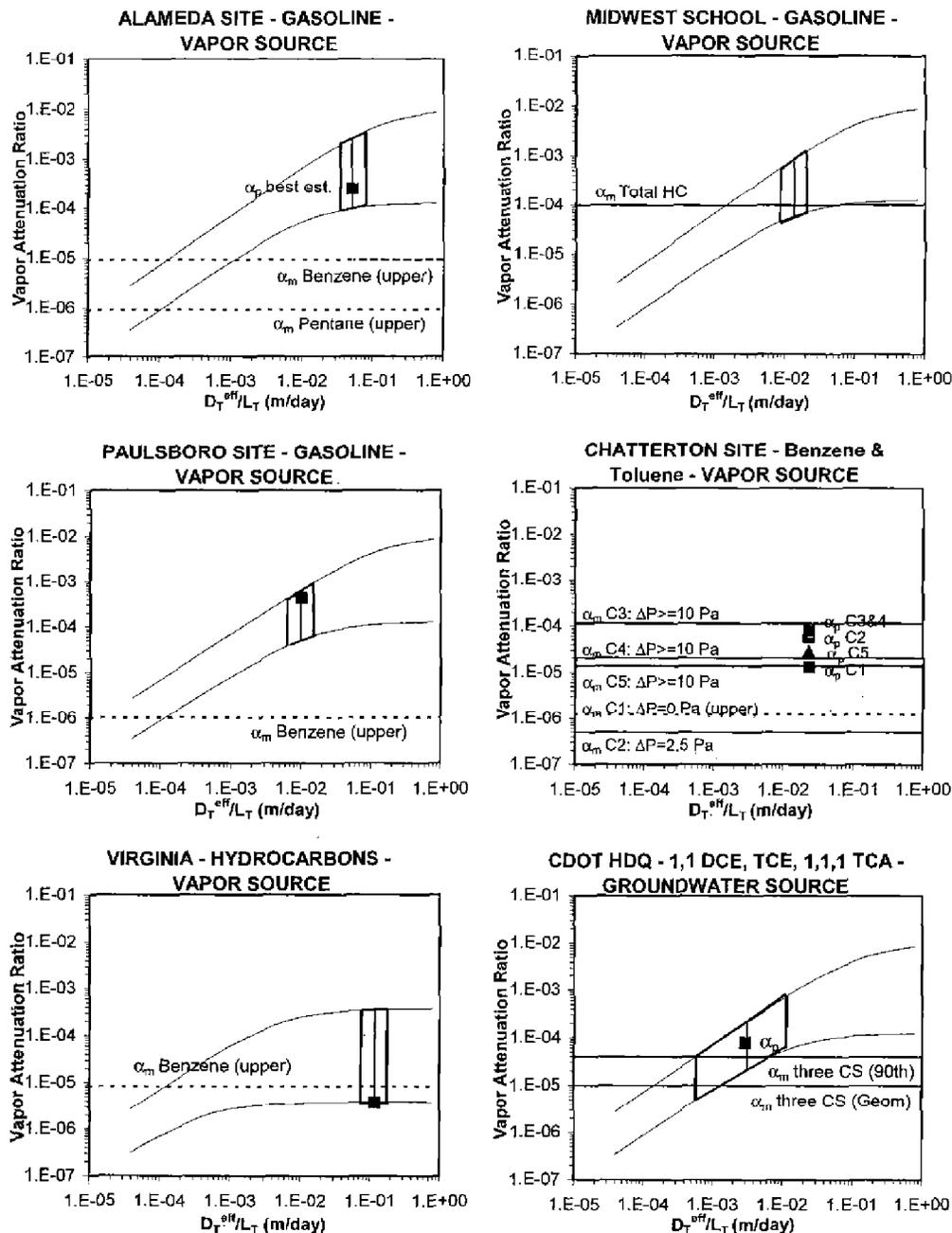
Figure 7a. Comparison between measured and J&E model-predicted vapor attenuation ratio (benzene). Upper and lower bound curves from Figure 6 are included. Dashed lines indicate that α_m is upper bound value. Symbols are best estimate α_p values.

shallow to moderate depths to contamination (0.5 to 3 m). Extensive residual nonaqueous phase liquid (NAPL) is present above the water table at the Chatterton site. There is evidence for some residual NAPL above the water table at the Alameda, Paulsboro, Virginia, and Midwest School sites. Indoor air testing was limited to a single or small number of buildings at each case study site. For petroleum sites, near-source vapor concentrations are available and therefore the α_m is directly calculated (vapor α_m).

At the Virginia, Chatterton (depressurization (ΔP) = 0 Pa case), Paulsboro, and Alameda sites, there was no difference between indoor air concentrations measured in building(s)

above the plume and in background areas, indicating that the α_m are unknown. For these sites, the α_m calculated using the measured indoor air concentrations are upper-bound values and range from $< 4.0 \times 10^{-7}$ to $< 9.0 \times 10^{-6}$. For the Chatterton $\Delta P = 2.5$ Pa case, there was a statistically significant difference in indoor and background indoor air concentrations; however, the α_m remained low (4.0×10^{-7} to 5.9×10^{-7}). For the Chatterton $\Delta P = 10$ and 30 Pa cases, there was a significant increase in indoor air concentrations and α_m.

At the Midwest School site, hydrocarbon-like odors were noted indoors during a period of relatively heavy rains and high water table in September 1992. Subsequent analysis of indoor
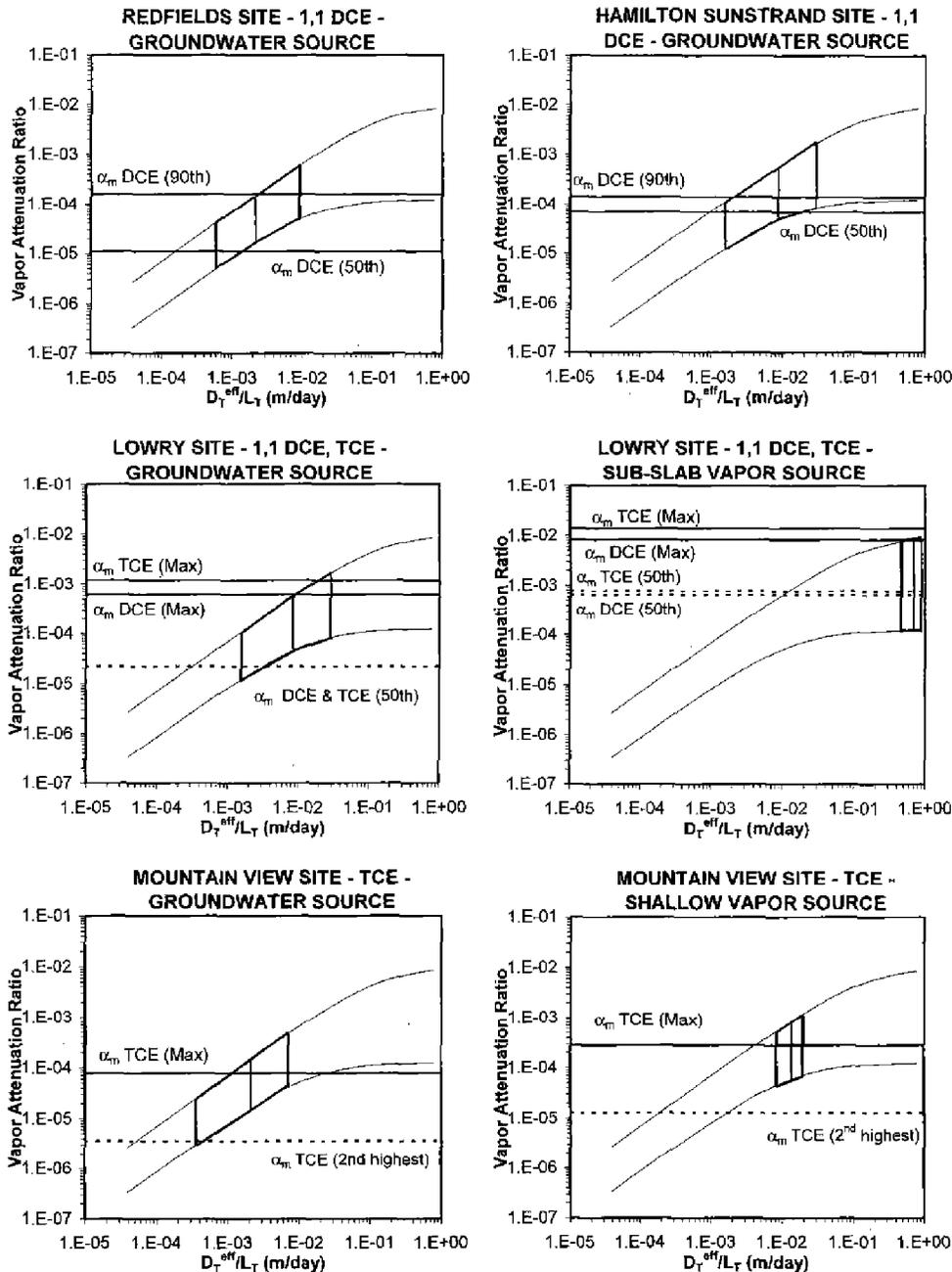
Figure 7b. Comparison between measured and J&E model-predicted vapor attenuation ratio (benzene). Upper and lower bound curves from Figure 6 are included. Dashed lines indicate that α_m is upper bound.

air during October 1992 indicated that hydrocarbon concentrations in indoor air were elevated but could not be conclusively distinguished from background sources at this time. However, the benzene (8 mg/m³) and total hydrocarbon concentrations (500 mg/m³) in an unventilated crawlspace below the ground floor were well above background levels. Based on a rough estimate of the source vapor concentrations and odor thresholds for hydrocarbons, the α_m may have been on the order of 1×10^{-4}.

Field data, including soil vapor profiles, indicate there was significant bioattenuation of hydrocarbon vapors for the Alameda and Chatterton ($\Delta P = 0$ and 2.5 Pa cases) sites. This

is consistent with other studies indicating that biodegradation can result in significant vadose zone attenuation of hydrocarbon vapors, provided sufficient O_2 is present (Ostendorf and Kampbell 1991; Ririe and Sweeney 1995). For higher underpressurizations (10 and 30 Pa), at the Chatterton site hydrocarbon vapor concentrations were elevated because of increased vapor flux from deeper soil, and reduced travel times (Hers et al. 2002). The relatively high α_m at the Chatterton site are from the combined effect of shallow contamination, relatively permeable soils, and high building underpressurizations.

The Paulsboro and Midwest School sites had elevated

hydrocarbon vapor levels directly below the building slab. For the Midwest School site, we speculate that elevated indoor hydrocarbon concentrations may have been a result of limited biodegradation owing to a large building and paved area, which reduced oxygen recharge, combined with factors that contributed to vapor intrusion into the building. These factors include building construction (i.e., crawlspace) and/or a sanitary sewer that was located near the water table within the hydrocarbon plume, which may have acted as a preferential pathway. At the Virginia site, contamination was shallow but no significant vapor intrusion was measured possibly because of the presence of fine-grained soils and/or building construction (i.e., tight foundations).

Comparison to Model Predictions for Petroleum Hydrocarbon Sites

Comparisons for the Chatterton ($\Delta P = 0$ and 2.5 Pa cases), Paulsboro, and Alameda sites indicate that the best estimate α_p are one to two orders of magnitude higher than the measured or upper bound α_m indicating the J&E model results in conservative predictions for these sites. Comparisons for the Chatterton ($\Delta P = 10$ and 30 Pa cases) and Virginia sites indicate the best estimate α_p are similar to the α_m. The high soil-gas advection rates for the Chatterton site resulted in significant vapor intrusion rates and hence similar α_p and α_m. For the Virginia site, the α_p is lower than at other sites owing to the influence of the fine-grained soils. For the Midwest site, the predictive envelope for α_p also intersects the α_m; however, the α_m is highly uncertain.

Measured Vapor Attenuation Ratios at Chlorinated Solvent Sites

At four case study sites with chlorinated solvent contamination (CDOT, Redfields, Hamilton, and Lowry), dissolved plumes have migrated below houses (Table 4). The depth to the water table at these sites ranged from ~4.8 to 10.7 m below ground surface. The ground water plumes at these sites are relatively long and narrow, resulting in significant spatial variability in dissolved ground water concentrations. At the fifth site (Mountain View), houses were constructed on top of a former leach field where chlorinated solvents had been disposed of. Therefore, in addition to ground water, shallow soil is likely contaminated at this site. Soil grain size at the sites is variable (Table 4). For all sites, the α_m are estimated using vapor concentrations predicted from ground water data (ground water α_m). For the Lowry and Mountain View sites, soil vapor data were also available; therefore, the α_m is also directly calculated using vapor data (unless otherwise noted, the α_m given below are for the ground water source scenario).

For the CDOT site, the differences in three chlorinated solvent concentrations (1,1 DCE, TCE, and 1,1,1 TCA) in houses above the plume and at background locations are statistically significant. However, the ground water and indoor air data were found to be unreliable at the periphery of the plume and therefore low ground water and indoor air concentrations were removed from the database prior to calculating the α_m. The resulting database comprises several hundred tests from apartments and houses. The methodology used to estimate α_m is further described in Johnson et al. (2000). The geometric mean and 90th percentile α_m for the CDOT site are 1.0×10^{-5} and 5.2×10^{-5}. Analysis of the intrusion database for the site indi-

cated no strong correlation between seasons and α_m, or difference between basement and slab-on-grade construction (personal communication, Dr. Jeff Kurtz, EMSI Inc.).

For the Redfields site, the difference in 1,1 DCE concentrations in houses above the plume and at background locations are statistically significant. A data screening procedure similar to that used for the CDOT site resulted in α_m only being estimated in areas where the 1,1 DCE concentrations in ground water exceeded 10 µg/L. A visual interpolation method was used to estimate ground water concentrations below houses. The resulting database comprises 65 houses nearest to the Redfields site. The 50th and 90th percentile α_m for the Redfields site are 1.1×10^{-5} and 1.2×10^{-4}. Synoptic data for the Redfields site indicated a slight correlation between indoor 1,1 DCE concentrations and season, for some houses, with winter-time values that were two to three times higher than summer-time values (personal communication, Dr. David Folkes 2000).

For the Hamilton site, the difference in 1,1 DCE concentrations in houses above the plume and at background locations are statistically significant. Because ground water data was limited, the attenuation ratio analysis is for a strip of 32 houses parallel and closest to the long axis of the plume (and wells) in the area with 1,1 DCE concentrations above ~10 µg/L. The 50th and 90th percentile α_m for the Hamilton site are 6.8×10^{-5} and 1.4×10^{-4}.

At the Lowry site, the database evaluated consists of more than a year of quarterly testing at 13 houses above and near the periphery of the plume. Concurrent testing of indoor air, and subslab vapor concentrations for houses with slab-on-grade or basement construction, and crawlspace air for houses with crawlspaces was conducted. At one house, the maximum TCE and 1,1 DCE concentrations in indoor air were 51 µg/m³ and 0.91 µg/m³, suggesting significant vapor intrusion. At three other houses, the TCE concentrations in indoor air were mostly between 5 and 15 µg/m³. Compared to published background data for TCE (Hers et al. 2001) and data for houses along the periphery of the plume, it is possible that concentrations at these three houses included a soil vapor-derived component. The indoor air concentrations were at background levels in remaining houses.

Measured vapor attenuation ratios are estimated for a subset of four Lowry houses with nearby ground water data. For this data subset, the maximum indoor air TCE concentration was 51 µg/m³, but exceeded 5 µg/m³ in only one house. Therefore, most α_m are upper bound values. When all data are used, the 50th percentile and maximum ground water α_m are 2.2×10^{-5} and 1.2×10^{-3} for TCE, and 2.2×10^{-5} and 6.2×10^{-4} for 1,1 DCE. The maximum, as opposed to 90th percentile α_m, was calculated owing to the relatively limited number of tests for this site. The Lowry subslab vapor concentrations were highly variable and elevated below certain houses (e.g., TCE up to 10,000 µg/m³), but near background levels below other houses above the plume. An analysis of the house data subset where indoor air TCE concentrations exceeded 5 µg/m³ and/or subslab TCE concentrations exceeded 1000 µg/m³ indicated that the 50th percentile and maximum subslab vapor α_m are 7.7×10^{-4} and 1.4×10^{-2}. Available synoptic data for the Lowry site indicated no significant seasonal variation in subslab or indoor air concentrations.

At the Mountain View site, indoor air in seven houses

above the contaminated area and two "background" houses in a noncontaminated area was tested on two occasions. The indoor TCE concentration in one house was 12 and 25 $\mu g/m^3$, whereas the TCE concentrations in remaining houses were at background levels (0.26 to 1.1 $\mu g/m^3$) (Wu 2000). The maximum ground water α_m is 7.8×10^{-5} while the shallow vapor maximum α_m is 2.8×10^{-4}.

When all five sites are evaluated, the results can be summarized as follows. The 50th percentile (or geometric mean) and 90th percentile (or maximum) α_m values for the ground water to indoor air pathway were remarkably similar for all sites (approximately 1×10^{-5} and 1×10^{-4}, respectively). For individual sites, there is significant house-to-house variability in α_m (e.g., two order of magnitude difference for Redfields site); however, based on the available data there appear to be only slight, if any, seasonally induced variations in vapor intrusion, and similar intrusion rates for houses with basement and slab-on-grade construction. Potential sources of variability in α_m include inaccurate estimation of water table ground water concentrations below houses, geological heterogeneity, differences in house construction and depressurization, and differences in ventilation rates and house activities during indoor air testing. At the Lowry and Mountain View sites, no significant vapor intrusion could be measured for most houses. One likely reason for the generally nonsignificant intrusion is that ground water concentrations are lower at these sites, compared to the CDOT, Redfields, and Hamilton sites. Another possible factor for the Mountain View site is the building construction, which consists of at-grade foundation slab with (moisture) vapor barrier. Overall, the results suggest that geologic conditions and diffusion rates have the greatest influence on vapor intrusion rates at the chlorinated solvent sites, and that building factors are less important.

Comparison to Model Predictions for Chlorinated Solvent Sites

Comparisons for sites with the most reliable data (CDOT, Redfields, and Hamilton) indicates that the predictive envelope for the α_p intersects the α_m. The centroid of the predictive envelope is in all cases higher than the 50th percentile α_m suggesting, on average, the J&E model would result in conservative predictions. For the CDOT site, the best estimate α_p is approximately eight times higher than the 50th percentile α_m. For the Lowry site, the predictive envelope is below the α_m for one house with significant vapor intrusion, indicating a nonconservative prediction in this case. For the Mountain View site, the predictive envelope for α_p intersects the maximum α_m. Overall, the J&E model in most cases results in conservative predictions (i.e., α_p is higher than α_m). However, the comparisons highlight the potential for nonconservative predictions if a combination of low Q_{soil} and low D_T^{eff}/L_T are used.

Tracer Method

There are several sites where tracer tests can be used to estimate α, which range from ~2 $\times 10^{-4}$ at the Alameda site to 4.5 $\times 10^{-2}$ at the Spokane River (Valley) sites (Table 4). The Spokane River sites were calculated using an assumed average house volume (500 m^3) and building ventilation rate (air changes per hour (ACH) = 0.5 hour^{-1})) and therefore are approximate. Soils at the Spokane River site are very permeable, and α is based on winter conditions (i.e., highest expected

seasonal building depressurization); therefore, the α for this site is considered an upper range value. It should be remembered that tracer studies represent α values for near-field boundary conditions and, therefore, are not representative of intrusion at many sites contaminated with VOCs. The tracer test α values are, however, consistent with the upper range of the J&E model predictions (Figure 6).

Flux Chamber Method

A method that has been used for radon assessments is the equivalent leakage area (ELA) method (Grimsrud et al. 1982; CSGB 1986). The ELA is obtained by developing an empirical relationship between the soil-gas flow into a building and building depressurization. Soil-gas flows are measured using flux chambers and mass flow meters. In one study involving multiple measurements of soil-gas flow through various building foundation cracks at 10 houses in Saskatchewan, Canada, the total house foundation ELA for the foundation edge cracks and utility penetrations ranged from 0.15 to 16.4 cm^2 (Figley and Snodgrass 1992). The contribution to total ELA from untrapped floor drains, present at a few houses, was excluded from this analysis since untrapped drains are uncommon in newer construction. For example, the National Building Code of Canada (1995) requires sealing of floor drainage systems that have the potential to allow soil-gas entry (Section 9.13.8.3).

The measured total ELA can be used to estimate soil-gas intrusion rates using the method in Figley (1997). A building depressurization representative of severe winter conditions (10 Pa), as proposed by Figley (1997), and possible values for the house volume (500 m^3) and building ventilation rate (0.3 ACH) produces α values between 3.6×10^{-4} and 3.8×10^{-2}. The α obtained in this manner is conservative because it assumes an unlimited and uniform soil-vapor source directly below the foundation slab (i.e., contaminants in vapor are replenished as fast as they are swept into the building).

Flux chamber tests have also been used to measure VOC flux rates through concrete cracks (Schmidt and Zdeb 1997; Hers and Zapf-Gilje 1998). Both studies indicated detectable VOCs were measured in soil gas transmitted through cracks, and the study by Hers and Zapf-Gilje (1998) indicated that the scaled-up flux for the entire building was of the same order as flux measured by the indoor VOC method.

Regulatory Implications

The J&E model is widely used for regulatory and guidance purposes in North America. Several agencies have developed generic screening criteria for the vapor intrusion pathway (Massachusetts 1993; Michigan 1998; Connecticut 1998). Semigeneric soil standards have been developed in Canada, based on two soil types (fine- and coarse-grained) and two building types (CCME 2000). Guidance recently developed by the U.S. EPA consists of a multitiered framework to evaluate the soil vapor intrusion pathway (U.S. EPA 2002). A primary (initial) screening step is used to identify sites with significant potential for vapor intrusion (e.g., odors, product in sumps or directly below foundation), and where indoor air monitoring and/or engineering controls is warranted. A secondary screening step involves the use of semigeneric curves for α, based

on soil type and depth, and target breathing concentrations in indoor air to back-calculate acceptable source ground water and soil vapor concentrations. Depending on the results of the secondary screening, there is the option to conduct a site-specific pathway assessment.

Derivation of regulatory criteria requires the prediction of cross-media transfer of contaminants, and vapor transport and intrusion into buildings. For the regulatory agencies cited previously (excluding Massachusetts), cross-media transfer between VOCs in ground water and soil vapor is predicted using the Henry's law constant assuming equilibrium partitioning. Under the Massachusetts guidance, the Henry's law constant is divided by 10 to account for source vapor concentrations that are typically lower than those predicted assuming equilibrium partitioning. The vapor attenuation ratios incorporated into regulatory criteria depend on whether the assumed contamination scenario is a dissolved ground water plume or an unsaturated zone contamination source. For a ground water source, the α incorporates vapor transport through both the capillary transition zone and unsaturated zone. For an unsaturated zone source, the α incorporates transport through just the unsaturated zone. For the agencies cited previously, the ground water source α ranges from 4.6×10^{-6} to 1.5×10^{-3} whereas the vapor source α ranges from 3.9×10^{-7} to 6.2×10^{-3}. An analysis of the previous regulatory criteria indicates that the key factor affecting the α is the Q_{soil} value chosen or estimated for predictive purposes. Of lessor importance is the assumed generic or semigeneric soil type.

When vapor attenuation ratios incorporated in regulatory criteria are compared to measured ratios for field studies presented in this paper, it is apparent that the low end of the regulatory range may not be conservative for some sites. Of greatest concern would be sites with nonbiodegradable chemicals, shallow to moderate depth contamination, and high advection potential (i.e., coarse soil, high building underpressurization).

Conclusions and Recommendations

A comprehensive evaluation of the J&E model characteristics and sensitivity, and comparisons of measured to model-predicted vapor attenuation ratios (α_m and α_p), have been provided for residential houses, ground-floor apartments, and small commercial buildings. Based on this analysis, the following conclusions can be drawn:

1. The J&E model is moderately too highly sensitive to soil-gas advection rate into the building (Q_{soil}), at D_T^{eff}/L_T values above $\sim 1 \times 10^{-3}$. Except when Q_{soil} is low, the J&E model is relatively insensitive to building foundation properties. At best, the range or uncertainty in J&E model predictions is about one order of magnitude when relatively good quality site-specific data is available.

2. Estimation of effective diffusion coefficient is subject to considerable uncertainty. Some of this uncertainty can be reduced through better site characterization, including careful lithological descriptions, testing of moisture content, grain size distribution and water retention, and appropriate consideration of the effect of surface barriers on soil moisture content.

3. Several radon and VOC tracer studies indicate that measured Q_{soil} values at coarse-grained soil sites, for single fam-

ily residences, ranged from ~ 1 to 10 L/min. Depending on the input values chosen, much lower Q_{soil} values can be predicted using the soil-gas advection model typically used in conjunction with the J&E model.

4. There are only a limited number of high quality and comprehensive field studies that can be used to help validate models for the vapor intrusion pathway.

5. For petroleum hydrocarbon sites, the vapor α_m for the Chatterton site (high ΔP cases) and Midwest site were on the order of 1×10^{-5} to 1×10^{-4} (the Midwest value is uncertain). For the remaining cases and sites, the possible upper bound vapor α_m ranged from $\sim 5 \times 10^{-7}$ to 1×10^{-5}.

6. For chlorinated solvent sites, the ground water α_m were on the order of 1×10^{-6} to 1×10^{-4} for the three sites with the most reliable data sets (CDOT, Redfields, and Hamilton). For one site with a smaller and somewhat less reliable data set (Lowry), the maximum ground water α_m was $\sim 1 \times 10^{-3}$ while the maximum subslab vapor α_m was $\sim 1 \times 10^{-2}$.

7. For the tracer and flux chamber studies, the α_m was on the order of 1×10^{-4} to 1×10^{-2}. In the context of VOC intrusion, these α_m represent conservative upper bounds owing to boundary conditions and tracer properties that are generally different than those at VOC-contaminated sites.

8. For almost all case studies, the best estimate J&E model-predicted α_p were one to two orders of magnitude less than the 50th percentile or median α_m, indicating that when best estimate and average conditions are evaluated, the J&E model predictions are conservative. There were a few cases studies where the best estimate α_p was less than the 90th percentile or maximum α_m, indicating the J&E model predictions are nonconservative for a small subset of houses or apartments. The comparisons also highlight the potential for non-conservative model predictions if a combination of low Q_{soil} and low D_T^{eff}/L_T are used.

The observed variability in α_m between different field sites, and individual houses at some sites, highlights the complexity of processes affecting vapor intrusion. Numerous factors potentially affect the vapor intrusion pathway including biodegradation, chemical transformation, sorption, contaminant source depletion, geologic heterogeneity, soil properties (moisture content, permeability, organic carbon content), building properties, meteorological conditions, and building ventilation rates. In light of this complexity, it is important to recognize the vapor intrusion modeling paradigm typically followed is a compartmental model for steady-state one-dimensional diffusion through soil, and diffusion and advection through a building foundation having an idealized edge or perimeter crack (J&E model). Often, a homogeneous soil is assumed, although it is relatively easy to model diffusion for multiple soil layers assuming site information is available (Johnson et al. 1998). Simulation of vapor transport through the building foundation and mixing of VOCs within the building airspace is highly simplified. Although not used for this study, it is noted that the J&E model has been modified to include first-order biodegradation for a dominant soil layer (Johnson et al. 1998) and oxygen-limited first-order biodegradation (Johnson et al. 2001).

Notwithstanding the above, the question remains: Can the

J&E model (or other similar screening models) be reliably used for the vapor intrusion pathway? Our answer is a qualified yes, provided that appropriate input values are used and the model sensitivity, uncertainty, and limitations are recognized. The answer may also depend on what the model is used for. For example, the use of the J&E model to set generic criteria is problematic owing to model sensitivity and uncertainty, and the wide range in possible site conditions. In our opinion, a semigeneric approach that incorporates site-specific information on critical factors affecting vapor intrusion (e.g., Q_{soil} and soil properties) improves on a single criteria approach. The technically preferred approach is to use the J&E model on a fully site-specific basis, and to calibrate model predictions using soil vapor profiles, and when possible, indoor air data. In all cases, an appropriate framework for model use and understanding of model characteristics is essential when using models for regulatory purposes.

Several data gaps and sources of uncertainty remain. Additional field-based studies should be conducted to evaluate the vapor intrusion pathway for different site conditions, and to more fully assess specific factors affecting vapor intrusion. Data that would contribute to a more in-depth pathway analysis include soil properties such as moisture content and porosity, soil vapor concentration profiles below buildings, building properties such as depressurization, and meteorological data. Further evaluation of biodegradation kinetics for hydrocarbon vapors, effect of surface barriers (e.g., buildings) on biodegradation, and chlorinated solvent transformation processes are also needed.

Acknowledgments

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Biographical Sketches

Ian Hers is completing Ph.D. studies at the University of British Columbia and is a senior consultant with Golder Associates Ltd. (ihers@golder.com) in Vancouver, British Columbia.

Loretta Y. Li is an associate professor in the Department of Civil Engineering at The University of British Columbia, with degrees from McGill University and Queen's University.

Paul C. Johnson is an associate professor and the assistant chair in the Department of Civil and Environmental Engineering at Arizona State University. His degrees are in chemical engineering, a B.S. from the University of California, Davis, and a Ph.D. from Princeton University.

Reidar Zapf-Gilje is an adjunct professor at the University of British Columbia (rzapf-gilje@shaw.ca) where he teaches graduate courses in the Department of Civil Engineering.

APPENDIX 4

EXAMPLE PRINTOUTS OF USEPA VAPOR INTRUSION MODELS

1. Groundwater to indoor air, highly-permeable soils, residential exposure scenario.
2. Groundwater to indoor air, low/moderately permeable soils, residential exposure scenario.
3. Groundwater to indoor air, highly-permeable soils, commercial/industrial exposure scenario.
4. Groundwater to indoor air, low/moderately permeable soils, commercial/industrial exposure scenario.
5. Soil to indoor air, residential exposure scenario.
6. Soil to indoor air, industrial/commercial exposure scenario.
7. Soil gas to indoor air, residential exposure scenario.
8. Soil gas to indoor air, industrial/commercial exposure scenario

GW-ADV
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes): **127184**

ENTER Initial groundwater conc., C_w (μg/L): [ ]

Chemical: **Tetrachloroethylene**

Groundwater Vapor Emissions To Indoor Air
Residential Exposure Scenario
High Permeability Soil Scenario

ENTER Average groundwater temperature, T_s (°C): **15**

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm): **15**

ENTER Depth below grade to water table, L_{WT} (cm): **300**

ENTER Totals must add up to value of L_{WT} (cell G28)
- Thickness of soil stratum A, h_A (cm): **100**
- Thickness of soil stratum B, h_B (cm): **200** (Enter value or 0)
- Thickness of soil stratum C, h_C (cm): (Enter value or 0)

ENTER Soil stratum directly above water table, (Enter A, B, or C): **B**

ENTER SCS soil type directly above water table: **CL**

ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability): **S**

ENTER User-defined stratum A soil vapor permeability, k_v (cm²) OR Average vapor flow rate into bldg. Q_{soil} (L/m) (Leave blank to calculate): **5**

	SCS soil type	soil dry bulk density, ρ_b (g/cm³)	soil total porosity, n (unitless)	soil water-filled porosity, θ_w (cm³/cm³)
Stratum A	S	1.50	0.430	0.15
Stratum B	CL	1.5	0.43	0.3
Stratum C	S			

ENTER Enclosed space floor thickness, L_{crack} (cm): **15**

ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²): **40**

ENTER Enclosed space floor length, L_B (cm): **961**

ENTER Enclosed space floor width, W_B (cm): **961**

ENTER Enclosed space height, H_B (cm): **244**

ENTER Floor-wall seam crack width, w (cm): **0.1**

ENTER Indoor air exchange rate, ER (1/h): **1**

ENTER Averaging time for carcinogens, AT_c (yrs): **70**

ENTER Averaging time for noncarcinogens, AT_{nc} (yrs): **30**

ENTER Exposure duration, ED (yrs): **30**

ENTER Exposure frequency, EF (days/yr): **350**

ENTER Target risk for carcinogens, TR (unitless): **1.0E-06**

ENTER Target hazard quotient for noncarcinogens, THQ (unitless): **0.2**

Used to calculate risk-based groundwater concentration.

END

DATA ENTRY SHEET

Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm³/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	6.0E-06	3.5E-02

END

DATA ENTRY SHEET

Parameter	Symbol	Units	Value
Exposure duration	τ	(sec)	9.46E+08
Source-building separation (Stratum A)	L_T	(cm)	285
Stratum A soil air-filled porosity	θ_a^A	(cm³/cm³)	0.280
Stratum B soil air-filled porosity	θ_a^B	(cm³/cm³)	0.130
Stratum C soil air-filled porosity	θ_a^C	(cm³/cm³)	ERROR
Stratum A soil effective total fluid saturation	S_{te}	(cm³)	0.257
Stratum A soil intrinsic permeability	k_i	(cm²)	1.00E-07
Stratum A soil relative air permeability	k_{rg}	(cm²)	0.703
Stratum A soil effective vapor permeability	k_v	(cm²)	7.04E-08
Thickness of capillary zone	L_{cz}	(cm)	46.88
Total porosity in capillary zone	n_{cz}	(cm³/cm³)	0.43
Air-filled porosity in capillary zone	$\theta_{a,cz}$	(cm³/cm³)	0.055
Water-filled porosity in capillary zone	$\theta_{w,cz}$	(cm³/cm³)	0.375
Floor-wall seam perimeter	X_{crack}	(cm)	3,844
Bldg. ventilation rate	$Q_{building}$	(cm³/s)	6.26E+04
Area of enclosed space below grade	A_B	(cm²)	9.24E+05
Crack-to-total area ratio	η	(unitless)	4.16E-04
Crack depth below grade	Z_{crack}	(cm)	15
Enthalpy of vaporization at ave. groundwater temperature	$\Delta H_{v,TS}$	(cal/mol)	9,502
Henry's law constant at ave. groundwater temperature	H_{TS}	(atm-m³/mol)	1.05E-02
Henry's law constant at ave. groundwater temperature	H'_{TS}	(unitless)	4.46E-01
Vapor viscosity at ave. soil temperature	μ_{TS}	(g/cm-s)	1.77E-04
Stratum A effective diffusion coefficient	D^{eff}_A	(cm²/s)	5.62E-03
Stratum B effective diffusion coefficient	D^{eff}_B	(cm²/s)	4.38E-04
Stratum C effective diffusion coefficient	D^{eff}_C	(cm²/s)	0.00E+00
Capillary zone effective diffusion coefficient	D^{eff}_{cz}	(cm²/s)	2.85E-05
Total overall effective diffusion coefficient	D^{eff}_T	(cm²/s)	1.42E-04
Diffusion path length	L_d	(cm)	285
Convection path length	L_p	(cm)	15
Source vapor conc.	C_{source}	(µg/m³)	4.46E+02
Crack radius	r_{crack}	(cm)	0.10
Average vapor flow rate into bldg.	Q_{soil}	(cm³/s)	8.33E+01
Crack effective diffusion coefficient	D^{crack}	(cm²/s)	5.62E-03
Area of crack	A_{crack}	(cm²)	3.84E+02
Exponent of equivalent foundation Peclet number	$\exp(Pe^f)$	(unitless)	2.87E+251
Infinite source indoor attenuation coefficient	α	(unitless)	7.30E-06
Infinite source bldg. conc.	$C_{building}$	(µg/m³)	3.26E-03
Unit risk factor	URF	(µg/m³)⁻¹	6.0E-06
Reference conc.	RfC	(mg/m³)	3.5E-02

END

DATA ENTRY SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., S (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
1.25E+02	2.24E+03	1.25E+02	2.00E+05	1.25E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

Soil Properties Lookup Table

SCS Soil Type	K_s (cm/h)	α_1 (1/cm)	N (unitless)	M (unitless)	n (cm³/cm³)	θ_r (cm³/cm³)	Mean Grain Diameter (cm)	Bulk Density (g/cm³)	θ_w (cm³/cm³)	SCS Soil Name
C	0.61	0.01496	1.253	0.2019	0.459	0.098	0.0092	1.43	0.215	Clay
CL	0.34	0.01581	1.416	0.2938	0.442	0.079	0.016	1.48	0.168	Clay Loam
L	0.50	0.01112	1.472	0.3207	0.399	0.061	0.020	1.59	0.148	Loam
LS	4.38	0.03475	1.746	0.4273	0.390	0.049	0.040	1.62	0.076	Loamy Sand
S	26.78	0.03524	3.177	0.6852	0.375	0.053	0.044	1.66	0.054	Sand
SC	0.47	0.03342	1.208	0.1722	0.385	0.117	0.025	1.63	0.197	Sandy Clay
SCL	0.55	0.02109	1.330	0.2481	0.384	0.063	0.029	1.63	0.146	Sandy Clay Loam
SI	1.82	0.00658	1.679	0.4044	0.489	0.050	0.046	1.35	0.167	Silt
SIC	0.40	0.01622	1.321	0.2430	0.481	0.111	0.0039	1.38	0.216	Silty Clay
SICL	0.46	0.00839	1.521	0.3425	0.482	0.090	0.0056	1.37	0.198	Silty Clay Loam
SIL	0.76	0.00506	1.663	0.3987	0.439	0.065	0.011	1.49	0.180	Silt Loam
SL	1.60	0.02667	1.449	0.3099	0.387	0.039	0.030	1.62	0.103	Sandy Loam

Chemical Properties Lookup Table

CAS No.	Chemical	Organic carbon partition coefficient, K_{oc} (cm³/g)	Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Pure component water solubility, S (mg/L)	Henry's law constant H' (unitless)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Unit risk factor, URF (μg/m³)⁻¹	Reference conc., RfC (mg/m³)	URF extrapolated (X)	RfC extrapolated (X)
56235	Carbon tetrachloride	1.74E+02	7.80E-02	8.80E-06	7.93E+02	1.25E+00	3.04E-02	25	349.90	556.60	7,127	4.3E-05	4.0E-02		
67641	Acetone	5.75E-01	1.24E-01	1.14E-05	1.00E+06	1.59E-03	3.88E-05	25	329.20	508.10	6,955		3.2E-02		X
67663	Chloroform	3.98E+01	1.04E-01	1.00E-05	7.92E+03	1.50E-01	3.67E-03	25	334.32	536.40	6,988	5.4E-06	4.9E-02		
71432	Benzene	5.90E+01	8.80E-02	9.80E-06	1.75E+03	2.28E-01	5.56E-03	25	353.24	562.16	7,342	2.9E-05	6.0E-02		
71556	1,1,1-Trichloroethane	1.10E+02	7.80E-02	8.80E-06	1.33E+03	7.05E-01	1.72E-02	25	347.24	545.00	7,136		2.2E+00		
74839	Methyl bromide (bromomethane)	9.00E+00	7.28E-02	1.21E-05	1.52E+04	2.56E-01	6.24E-03	25	276.71	467.00	5,714		4.9E-03		
74873	Methyl chloride (chloromethane)	3.50E+01	1.10E-01	6.50E-06	5.32E+03	3.61E-01	8.82E-03	25	249.00	416.25	5,115	7.4E-06	3.0E-01	X	X
75003	Chloroethane (ethyl chloride)	1.47E+01	1.04E-01	1.15E-05	5.70E+03	4.51E-01	1.10E-02	25	285.30	460.40	5,879	8.3E-07	1.0E+01		X
75014	Vinyl chloride (chloroethene)	1.86E+01	1.06E-01	1.23E-05	2.76E+03	1.11E+00	2.70E-02	25	259.25	432.00	5,250		1.0E-01		
75092	Methylene chloride	1.11E+01	1.01E-01	1.17E-05	1.30E+04	1.32E-01	3.23E-03	25	313.00	510.00	6,706		3.0E+00		
75274	Bromodichloromethane	5.50E+01	2.98E-02	1.06E-05	4.50E+03	6.56E-02	1.60E-03	25	363.15	585.85	7,800				
75343	1,1-Dichloroethane	3.16E+01	7.42E-02	9.10E-06	5.06E+03	2.30E-01	5.62E-03	25	330.55	523.00	6,895				
75354	1,1-Dichloroethylene	5.89E+01	9.00E-02	1.04E-05	2.25E+03	1.07E+00	2.61E-02	25	304.75	576.05	6,247	5.7E-05	2.0E-01	X	X
78875	1,2-Dichloropropane	4.37E+01	7.82E-02	9.00E-06	2.80E+03	1.15E-01	2.80E-03	25	369.52	572.00	7,590		4.0E-03		
78933	Methylethylketone (2-butanone)	4.50E+00	6.08E-02	9.80E-06	2.68E+05	2.74E-03	5.69E-05	25	352.50	536.78	7,481		5.0E+00		
79005	1,1,2-Trichloroethane	5.01E+01	6.06E-02	8.80E-06	4.42E+03	3.74E-02	9.13E-04	25	386.15	602.00	8,322	1.6E-05			
79016	Trichloroethylene	1.66E+02	7.90E-02	9.10E-06	1.10E+03	4.22E-01	1.03E-02	25	360.36	544.20	7,505	2.0E-06	6.0E-01	X	X
79345	1,1,2,2-Tetrachloroethane	9.37E+01	7.10E-02	7.90E-06	2.97E+03	1.41E-02	3.45E-04	25	419.60	661.15	8,996	5.8E-05			
83329	Acenaphthene	4.90E+03	4.21E-02	7.69E-06	4.24E+00	6.36E-03	1.55E-04	25	550.54	803.15	12,155		2.1E-01		X
86737	Fluorene	1.38E+04	3.63E-02	7.88E-06	1.98E+00	1.55E-04	7.70E-05	25	570.44	870.00	12,666		1.4E-01		X
90120	1-(2-)Methylnaphthalene	7.20E+02	5.90E-02	7.50E-06	2.60E+01	1.19E-02	2.90E-04	25	514.26	761.00	12,600				X
91203	Naphthalene	1.19E+03	5.90E-02	7.50E-06	3.10E+01	1.98E-02	4.83E-04	25	491.14	748.40	10,373	3.4E-05	9.0E-03	X	X
95501	1,2-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	1.56E+02	7.79E-02	1.90E-03	25	453.57	705.00	9,700		2.0E-01		X
95578	2-Chlorophenol	3.98E+02	5.01E-02	9.46E-06	2.20E+04	1.60E-02	3.91E-04	25	447.53	675.00	9,572		1.8E-02		X
95954	2,4,5-Trichlorophenol	8.90E+02	2.91E-02	7.03E-06	1.19E+03	2.18E-04	5.34E-03?	25	526.15	739.13	13,000			X	
100414	Ethylbenzene	3.63E+02	7.50E-02	7.80E-06	1.69E+02	3.23E-01	7.88E-03	25	409.34	617.20	8,501	2.5E-06	1.0E+00		
100425	Styrene	7.76E+02	7.10E-02	8.00E-06	3.10E+02	1.13E-01	2.75E-03	25	418.31	636.00	8,737		1.0E+00		X
105679	2,4-Dimethylphenol	4.00E+01	5.84E-02	8.69E-06	7.87E+03	6.97E-04	1.70E-05	25	452.00	685.00	8,523				
106467	1,4-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	7.38E+01	9.96E-02	2.43E-03	25	447.21	684.75	8,773	8.1E-01			
106934	1,2-Dibromoethane (ethylene dibromide)	2.81E+01	7.90E-02	8.06E-06	3.52E+03	3.40E-02	3.20E-04	25	404.60	583.00	9,271	6.0E-04	9.1E-03	X	
107062	1,2-Dichloroethane	1.74E+01	1.04E-01	9.90E-06	8.52E+03	4.01E-02	9.79E-04	25	356.66	561.00	8,310	2.6E-05			
108101	Methyl Isobutyl Ketone	1.34E+02	7.50E-02	7.80E-06	1.90E+04	5.74E-03	1.40E-04	25	389.00	575.00	7,643		8.1E-02		
108383	m-Xylene	4.07E+02	7.00E-02	7.80E-06	1.61E+02	3.01E-01	7.34E-03	25	412.27	617.00	8,523		7.0E-01		
108883	Toluene	1.82E+02	8.70E-02	8.60E-06	5.26E+02	2.72E-01	6.64E-03	25	383.78	591.79	8,410		3.0E-01		
108907	Chlorobenzene	2.19E+02	7.30E-02	8.70E-06	4.72E+02	1.52E-01	3.70E-03	25	404.87	632.40	7,930		6.0E-02		X
111444	Bis(2-chloroethyl)ether	7.60E+01	6.92E-02	7.53E-06	1.72E+04	7.38E-04	1.80E-05	25	451.15	659.79	10,803	7.1E-04			
120127	Anthracene	2.35E+04	3.24E-02	7.74E-06	4.34E-02	2.67E-03	6.50E-05	25	615.18	873.00	13,121				X
120821	1,2,4-Trichlorobenzene	1.78E+03	3.00E-02	8.23E-06	3.00E+02	5.82E-02	1.42E-03	25	486.15	725.00	10,471			X	
124481	Dibromochloromethane	4.68E+02	9.60E-02	1.00E-05	2.00E+03	3.49E-02	8.50E-04	25	416.14	678.20	5,900	2.7E-05		X	X
127184	Tetrachloroethylene	1.55E+02	7.20E-02	8.20E-06	2.00E+02	7.54E-01	1.84E-02	25	394.40	620.20	8,288		3.5E-02		
129000	Pyrene	1.05E+05	2.72E-02	7.24E-06	1.35E-01	4.51E-04	1.10E-05	25	667.95	936	14370				X
156592	cis-1,2-Dichloroethylene	3.55E+01	7.36E-02	1.13E-05	3.50E+03	1.67E-01	4.08E-03	25	333.65	516.5	7192		3.5E-02		X
156605	trans-1,2-Dichloroethylene	5.25E+01	7.07E-02	1.19E-05	6.30E+03	3.85E-01	9.38E-03	25	320.85	544	6717		7.0E-02		X
542756	1,3-Dichloropropene	4.57E+01	6.26E-02	1.00E-05	2.80E+03	7.26E-01	1.77E-02	25	381.15	587.38	7900	1.6E-05	7.0E-02		X
1634044	MTBE	6.00E+00	8.00E-02	1.00E-05	5.10E+04	2.41E-02	5.87E-04	25	328.3	497.1	6677.66	2.6E-07	8.0E+00		X

GW-ADV
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)   YES [ ]

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)   YES [X]   OR   [ ]

ENTER Chemical CAS No. (numbers only, no dashes) → 127184

ENTER Initial groundwater conc., C_w, (µg/L)

Tetrachloroethylene ← Chemical

> **Groundwater Vapor Emissions To Indoor Air**
> **Residential Exposure Scenario**
> **Moderate/Low Permeability Soil Scenario**

ENTER Average groundwater temperature, T_s (°C) → 15

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm) → 15

ENTER Depth below grade to water table, L_{WT} (cm) → 300

ENTER Thickness of soil stratum A, h_A (cm) → 100

ENTER Thickness of soil stratum B, h_B (cm) (Enter value or 0) → 200

ENTER Thickness of soil stratum C, h_C (cm) (Enter value or 0)

Totals must add up to value of L_{WT} (cell G28)

ENTER Soil stratum directly above water table, (Enter A, B, or C) → B

ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability) → LS

ENTER Soil stratum A SCS soil type → SI

ENTER Soil stratum B SCS soil type → B

ENTER Soil stratum C SCS soil type → SI

Lookup Soil Parameters

ENTER User-defined stratum A soil vapor permeability, k_v (cm²)

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³) → 1.50

ENTER Stratum A soil total porosity, n^A (unitless) → 0.430

ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³) → 0.15

ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³) → 1.5

ENTER Stratum B soil total porosity, n^B (unitless) → 0.43

ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³) → 0.3

ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)

ENTER Stratum C soil total porosity, n^C (unitless)

ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)

ENTER Enclosed space floor thickness, L_{crack} (cm) → 15

ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²) → 40

ENTER Enclosed space floor length, L_B (cm) → 961

ENTER Enclosed space floor width, W_B (cm) → 961

ENTER Enclosed space height, H_B (cm) → 244

ENTER Floor-wall seam crack width, w (cm) → 0.1

ENTER Indoor air exchange rate, ER (1/h) → 5

ENTER Average vapor flow rate into bldg. Q_{soil} (L/m) OR Leave blank to calculate

ENTER Averaging time for carcinogens, AT_c (yrs) → 70

ENTER Averaging time for noncarcinogens, AT_{nc} (yrs) → 30

ENTER Exposure duration, ED (yrs) → 30

ENTER Exposure frequency, EF (days/yr) → 350

ENTER Target risk for carcinogens, TR (unitless) → 1.0E-06

ENTER Target hazard quotient for noncarcinogens, THQ (unitless) → 0.2

Used to calculate risk-based groundwater concentration.

DATA ENTRY SHEET

Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm³/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	6.0E-06	3.5E-02

END

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm³/cm³)	Stratum B soil air-filled porosity, θ_a^B (cm³/cm³)	Stratum C soil air-filled porosity, θ_a^C (cm³/cm³)	Stratum A soil effective total fluid saturation, S_{te} (cm³/cm³)	Stratum A soil intrinsic permeability, k_i (cm²)	Stratum A soil relative air permeability, k_{rg} (cm²)	Stratum A soil effective vapor permeability, k_v (cm²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm³/cm³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm³/cm³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm³/cm³)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	285	0.280	0.130	ERROR	0.265	1.64E-08	0.824	1.35E-08	163.04	0.43	0.048	0.382	3,844

Bldg. ventilation rate, $Q_{building}$ (cm³/s)	Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm²/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm²/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm²/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm²/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm²/s)	Diffusion path length, L_d (cm)
6.26E+04	9.24E+05	4.16E-04	15	9.502	1.05E-02	4.46E-01	1.77E-04	5.62E-03	4.38E-04	0.00E+00	2.02E-05	3.48E-05	285

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $\exp(Pe')$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m³)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m³)
15	4.46E+02	0.10	8.33E+01	5.62E-03	3.84E+02	2.87E+251	1.80E-06	8.03E-04	6.0E-06	3.5E-02

END

DATA ENTRY SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

INCREMENTAL RISK CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
5.05E+02	9.09E+03	5.05E+02	2.00E+05	5.05E+02

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

GW-ADV
Version 3.0; 02/03

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)   YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)   YES [X]

Groundwater Vapor Emissions To Indoor Air
Commercial/Industrial Exposure Scenario
High Permeability Soil Scenario

ENTER Chemical CAS No. (numbers only, no dashes)   **127184**

ENTER Initial groundwater conc., C_w (µg/L)   [ ]

Chemical: **Tetrachloroethylene**

ENTER Average groundwater temperature, T_s (°C)   **15**

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)   **15**

ENTER Depth below grade to water table, L_{WT} (cm)   **300**

ENTER Totals must add up to value of L_{WT} (cell G28)
- Thickness of soil stratum A, h_A (cm) (Enter value or 0)   **100**
- Thickness of soil stratum B, h_B (cm) (Enter value or 0)   **200**
- Thickness of soil stratum C, h_C (cm)   [ ]

ENTER Soil stratum directly above water table, (Enter A, B, or C)   **B**

ENTER Soil stratum A SCS soil type   **S** (Lookup Soil Parameters)

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)   **1.50**

ENTER Stratum A soil total porosity, n^A (unitless)   **0.430**

ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)   **0.15**

ENTER Stratum B SCS soil type   **CL** (Lookup Soil Parameters)

ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)   **1.5**

ENTER Stratum B soil total porosity, n^B (unitless)   **0.43**

ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)   **0.3**

ENTER Soil stratum directly above water table   SCS soil type   **CL** (Lookup Soil Parameters)

ENTER Stratum C SCS soil type   [ ] (Lookup Soil Parameters)

ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)   [ ]

ENTER Stratum C soil total porosity, n^C (unitless)   [ ]

ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)   [ ]

ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)   **S**

ENTER User-defined stratum A soil vapor permeability, k_v (cm²)   [ ]   OR

ENTER Enclosed space floor thickness, L_{crack} (cm)   **15**

ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)   **40**

ENTER Enclosed space floor length, L_B (cm)   **961**

ENTER Enclosed space floor width, W_B (cm)   **961**

ENTER Enclosed space height, H_B (cm)   **244**

ENTER Floor-wall seam crack width, w (cm)   **0.1**

ENTER Indoor air exchange rate, ER (1/h)   **2**

ENTER Average vapor flow rate into bldg., Q_{soil} (L/m)
OR
Leave blank to calculate   **5**

ENTER Averaging time for carcinogens, AT_c (yrs)   **70**

ENTER Averaging time for noncarcinogens, AT_{nc} (yrs)   **25**

ENTER Exposure duration, ED (yrs)   **25**

ENTER Exposure frequency, EF (days/yr)   **250**

ENTER Target risk for carcinogens, TR (unitless)   **1.0E-06**

ENTER Target hazard quotient for noncarcinogens, THQ (unitless)   **0.2**

Used to calculate risk-based groundwater concentration.

MORE →

END

Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm³/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	6.0E-06	3.5E-02

END

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm³/cm³)	Stratum B soil air-filled porosity, θ_a^B (cm³/cm³)	Stratum C soil air-filled porosity, θ_a^C (cm³/cm³)	Stratum A soil total fluid saturation, S_{te} (cm³/cm³)	Stratum A soil intrinsic permeability, k_i (cm²)	Stratum A soil relative air permeability, k_{rg} (cm²)	Stratum A soil effective vapor permeability, k_v (cm²)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm³/cm³)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm³/cm³)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm³/cm³)	Floor-wall seam perimeter, X_{crack} (cm)
7.88E+08	285	0.280	0.130	ERROR	0.257	1.00E-07	0.703	7.04E-08	46.88	0.43	0.055	0.375	3,844

Bldg. ventilation rate, $Q_{building}$ (cm³/s)	Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm²/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm²/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm²/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm²/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm²/s)	Diffusion path length, L_d (cm)
1.25E+05	9.24E+05	4.16E-04	15	9,502	1.05E-02	4.46E-01	1.77E-04	5.62E-03	4.38E-04	0.00E+00	2.85E-05	1.42E-04	285

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m³)	Unit risk factor, URF (µg/m³)$^{-1}$	Reference conc., RfC (mg/m³)
15	4.46E+02	0.10	8.33E+01	5.62E-03	3.84E+02	2.87E+251	3.65E-06	1.63E-03	6.0E-06	3.5E-02

END

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

INCREMENTAL RISK CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., S (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)		Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
4.18E+02	6.28E+03	4.18E+02	2.00E+05	4.18E+02		NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

END

SCROLL
DOWN
TO "END"

GW-ADV
Version 3.0, 02/03

Reset to
Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES

$\boxed{\text{X}}$

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES

**Groundwater Vapor Emissions To Indoor Air
Commercial/Industrial Exposure Scenario
Moderate/Low Permeability Soil Scenario**

ENTER Chemical CAS No. (numbers only, no dashes)	**ENTER** Initial groundwater conc., C_w (μg/L)	Chemical
127184		Tetrachloroethylene

ENTER Average soil/ groundwater temperature, T_s (°C)	**ENTER** Depth below grade to bottom of enclosed space floor, L_F (cm)	**ENTER** Depth below grade to water table, L_{WT} (cm)
15	15	300

ENTER Totals must add up to value of L_{WT} (cell G28)

Thickness of soil stratum A, h_A (Enter value or 0) (cm)	Thickness of soil stratum B, h_B (Enter value or 0) (cm)	Thickness of soil stratum C, h_C (Enter value or 0) (cm)	Soil stratum directly above water table, (Enter A, B, or C)	**ENTER** SCS soil type directly above water table
100	200		B	

ENTER Stratum A SCS soil type	**ENTER** Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	**ENTER** Stratum A soil total porosity, n^A (unitless)	**ENTER** Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)
LS	1.50	0.430	0.15

Lookup Soil Parameters

ENTER Stratum B SCS soil type	**ENTER** Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	**ENTER** Stratum B soil total porosity, n^B (unitless)	**ENTER** Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)
SI	1.5	0.43	0.3

Lookup Soil Parameters

ENTER Stratum C SCS soil type	**ENTER** Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	**ENTER** Stratum C soil total porosity, n^C (unitless)	**ENTER** Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
LS			

ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	**ENTER** SCS soil type directly above water table	**ENTER** User-defined stratum A soil vapor permeability, k_v (cm^2)
B	SI	

OR

ENTER Enclosed space floor thickness, L_{crack} (cm)	**ENTER** Soil-bldg. pressure differential, ΔP (g/cm-s^2)	**ENTER** Enclosed space floor length, L_B (cm)	**ENTER** Enclosed space floor width, W_B (cm)	**ENTER** Enclosed space height, H_B (cm)	**ENTER** Floor-wall seam crack width, w (cm)	**ENTER** Indoor air exchange rate, ER (1/h)
15	40	961	961	244	0.1	2

ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
5

ENTER Averaging time for carcinogens, AT_c (yrs)	**ENTER** Averaging time for noncarcinogens, AT_{nc} (yrs)	**ENTER** Exposure duration, ED (yrs)	**ENTER** Exposure frequency, EF (days/yr)	**ENTER** Target risk for carcinogens, TR (unitless)	**ENTER** Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	0.2

Used to calculate risk-based groundwater concentration.

MORE
MORE
MORE
MORE
END

DATA ENTRY SHEET

Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm³/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	6.0E-06	3.5E-02

END

Parameter	Symbol	Units	Value
Exposure duration,	τ	(sec)	7.88E+08
Source-building separation,	L_T	(cm)	285
Stratum A soil air-filled porosity,	θ_a^A	(cm³/cm³)	0.280
Stratum B soil air-filled porosity,	θ_a^B	(cm³/cm³)	0.130
Stratum C soil air-filled porosity,	θ_a^C	(cm³/cm³)	0.265
Stratum A soil effective total fluid saturation,	S_{te}	(cm³/cm³)	ERROR
Stratum A soil intrinsic permeability,	k_i	(cm²)	1.64E-08
Stratum A soil relative air permeability,	k_{rg}	(cm²)	0.824
Stratum A soil effective vapor permeability,	k_v	(cm²)	1.35E-08
Thickness of capillary zone,	L_{cz}	(cm)	163.04
Total porosity in capillary zone,	n_{cz}	(cm³/cm³)	0.43
Air-filled porosity in capillary zone,	$\theta_{a,cz}$	(cm³/cm³)	0.048
Water-filled porosity in capillary zone,	$\theta_{w,cz}$	(cm³/cm³)	0.382
Floor-wall seam perimeter,	X_{crack}	(cm)	3,844

Parameter	Symbol	Units	Value
Bldg. ventilation rate,	$Q_{building}$	(cm³/s)	1.25E+05
Area of enclosed space below grade,	A_B	(cm²)	9.24E+05
Crack-to-total area ratio,	η	(unitless)	4.16E-04
Crack depth below grade,	Z_{crack}	(cm)	15
Enthalpy of vaporization at ave. groundwater temperature,	$\Delta H_{v,TS}$	(cal/mol)	9,502
Henry's law constant at ave. groundwater temperature,	H_{TS}	(atm-m³/mol)	1.05E-02
Henry's law constant at ave. groundwater temperature,	H'_{TS}	(unitless)	4.46E-01
Vapor viscosity at ave. soil temperature,	μ_{TS}	(g/cm-s)	1.77E-04
Stratum A effective diffusion coefficient,	D_A^{eff}	(cm²/s)	5.62E-03
Stratum B effective diffusion coefficient,	D_B^{eff}	(cm²/s)	4.38E-04
Stratum C effective diffusion coefficient,	D_C^{eff}	(cm²/s)	0.00E+00
Capillary zone effective diffusion coefficient,	D_{cz}^{eff}	(cm²/s)	2.02E-05
Total overall effective diffusion coefficient,	D_T^{eff}	(cm²/s)	3.48E-05

Parameter	Symbol	Units	Value
Convection path length,	L_p	(cm)	15
Source vapor conc.,	C_{source}	(µg/m³)	4.46E+02
Crack radius,	r_{crack}	(cm)	0.10
Average vapor flow rate into bldg.,	Q_{soil}	(cm³/s)	8.33E+01
Crack effective diffusion coefficient,	D^{crack}	(cm²/s)	5.62E-03
Area of crack,	A_{crack}	(cm²)	3.84E+02
Exponent of equivalent foundation Peclet number,	$\exp(Pe')$	(unitless)	2.87E+251
Infinite source indoor attenuation coefficient,	α	(unitless)	9.01E-07
Infinite source bldg. conc.,	$C_{building}$	(µg/m³)	4.02E-04
Unit risk factor,	URF	(µg/m³)⁻¹	6.0E-06
Reference conc.,	RfC	(mg/m³)	3.5E-02

END

DATA ENTRY SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

INCREMENTAL RISK CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (μg/L)	Indoor exposure groundwater conc., noncarcinogen (μg/L)	Risk-based indoor exposure groundwater conc., S (μg/L)	Pure component water solubility, S (μg/L)	Final indoor exposure groundwater conc., (μg/L)
1.70E+03	2.54E+04	1.70E+03	2.00E+05	1.70E+03

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

SL-ADV
Version 3.0, 02/03

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)   YES

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)   YES   X   OR

Soil Vapor Emissions To Indoor Air		
Residential Exposure Scenario		

Chemical   Tetrachloroethylene

ENTER
Chemical CAS No. (numbers only, no dashes)   127184

ENTER
Initial soil conc., C_R (µg/kg)

ENTER
Average soil temperature, T_S (°C)   20

ENTER
Depth below grade to bottom of enclosed space floor, L_F (cm)   15

ENTER
Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_t (cm)   15

ENTER
Depth below grade to top of contamination, (enter value or 0) h_A (cm)   215

ENTER
Totals must add up to value of L_t (cell G28)
Thickness of soil stratum A, (Enter value or 0) h_B (cm)   15

Thickness of soil stratum B, (Enter value or 0) h_C (cm)

ENTER
Soil stratum A SCS soil type (used to estimate soil vapor permeability)   S   OR

ENTER
User-defined stratum A soil vapor permeability, k_v (cm²)

MORE ↓

ENTER
Stratum A SCS soil type   S

ENTER
Stratum A soil dry bulk density, ρ_b^A (g/cm³)   1.5

ENTER
Stratum A soil total porosity, n^A (unitless)   0.43

ENTER
Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)   0.15

ENTER
Stratum A soil organic carbon fraction, f_{oc}^A (unitless)   0.006

ENTER
Stratum B SCS soil type

ENTER
Stratum B soil dry bulk density, ρ_b^B (g/cm³)

ENTER
Stratum B soil total porosity, n^B (unitless)

ENTER
Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)

ENTER
Stratum B soil organic carbon fraction, f_{oc}^B (unitless)

ENTER
Stratum C SCS soil type

ENTER
Stratum C soil dry bulk density, ρ_b^C (g/cm³)

ENTER
Stratum C soil total porosity, n^C (unitless)

ENTER
Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)

ENTER
Stratum C soil organic carbon fraction, f_{oc}^C (unitless)

MORE ↓

ENTER
Enclosed space floor thickness, L_{crack} (cm)   15

ENTER
Soil-bldg. pressure differential, ΔP (g/cm²)   40

ENTER
Enclosed space floor length, L_B (cm)   961

ENTER
Enclosed space floor width, W_B (cm)   961

ENTER
Enclosed space height, H_B (cm)   244

ENTER
Floor-wall seam crack width, w (cm)   0.1

ENTER
Indoor air exchange rate, ER (1/h)   1

ENTER
Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)   5

MORE ↓

ENTER
Averaging time for carcinogens, AT_c (yrs)   70

ENTER
Averaging time for noncarcinogens, AT_{nc} (yrs)   30

ENTER
Exposure duration, ED (yrs)   30

ENTER
Exposure frequency, EF (days/yr)   350

ENTER
Target risk for carcinogens, TR (unitless)   1.0E-06

ENTER
Target hazard quotient for noncarcinogens, THQ (unitless)   0.2

Used to calculate risk-based soil concentration.

END

DATA ENTRY SHEET

Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm³/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)	Physical state at soil temperature, (S,L,G)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	6.0E-06	3.5E-02	L

END

DATA ENTRY SHEET

Parameter	Symbol (units)	Value
Exposure duration,	τ (sec)	9.46E+08
Source-building separation,	L_T (cm)	1
Stratum A soil air-filled porosity,	θ_a^A (cm³/cm³)	0.280
Stratum B soil air-filled porosity,	θ_a^B (cm³/cm³)	ERROR
Stratum C soil air-filled porosity,	θ_a^C (cm³/cm³)	ERROR
Stratum A soil total fluid saturation,	S_{te} (cm³/cm³)	0.257
Stratum A soil intrinsic permeability,	k_i (cm²)	1.01E-07
Stratum A soil relative air permeability,	k_{rg} (cm²)	0.703
Stratum A soil effective vapor permeability,	k_v (cm²)	7.10E-08
Floor-wall seam perimeter,	X_{crack} (cm)	3.844
Initial soil concentration used,	C_R (µg/kg)	1.00E+00
Bldg. ventilation rate,	$Q_{building}$ (cm³/s)	6.26E+04

Parameter	Symbol (units)	Value
Area of enclosed space below grade,	A_B (cm²)	9.24E+05
Crack-to-total area ratio,	η (unitless)	4.16E-04
Crack depth below grade,	Z_{crack} (cm)	15
Enthalpy of vaporization at ave. soil temperature,	$\Delta H_{v,TS}$ (cal/mol)	9,451
Henry's law constant at ave. soil temperature,	H_{TS} (atm-m³/mol)	1.40E-02
Henry's law constant at ave. soil temperature,	H'_{TS} (unitless)	5.83E-01
Vapor viscosity at ave. soil temperature,	μ_{TS} (g/cm-s)	1.78E-04
Stratum A effective diffusion coefficient,	D_A^{eff} (cm²/s)	5.62E-03
Stratum B effective diffusion coefficient,	D_B^{eff} (cm²/s)	0.00E+00
Stratum C effective diffusion coefficient,	D_C^{eff} (cm²/s)	0.00E+00
Total overall effective diffusion coefficient,	D_T^{eff} (cm²/s)	5.62E-03
Diffusion path length,	L_d (cm)	1
Convection path length,	L_p (cm)	15

Parameter	Symbol (units)	Value
Soil-water partition coefficient,	K_d (cm³/g)	9.30E-01
Source vapor conc.,	C_{source} (µg/m³)	5.12E+02
Crack radius,	r_{crack} (cm)	0.10
Average vapor flow rate into bldg.,	Q_{soil} (cm³/s)	8.33E+01
Crack effective diffusion coefficient,	D^{crack} (cm²/s)	5.62E-03
Area of crack,	A_{crack} (cm²)	3.84E+02
Exponent of equivalent foundation Peclet number,	$\exp(Pe)$ (unitless)	2.88E+251
Infinite source indoor attenuation coefficient,	α (unitless)	NA
Infinite source bldg. conc.,	$C_{building}$ (µg/m³)	NA
Finite source β term,	β term (unitless)	6.32E+01
Finite source ψ term,	ψ term (sec)⁻¹	1.92E-03
Time for source depletion,	t_D (sec)	1.70E+07
Exposure duration > time for source depletion	(YES/NO)	YES

Parameter	Symbol (units)	Value
Finite source indoor attenuation coefficient,	$\langle\alpha\rangle$ (unitless)	NA
Mass limit source bldg. conc.,	$C_{building}$ (µg/m³)	4.68E-03
		NA
Final finite source bldg. conc.,	$C_{building}$ (µg/m³)	4.68E-03
Unit risk factor,	URF (µg/m³)⁻¹	6.0E-06
Reference conc.,	RfC (mg/m³)	3.5E-02

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (μg/kg)	Indoor exposure soil conc., noncarcinogen (μg/kg)	Risk-based indoor exposure soil conc., (μg/kg)	Soil saturation conc., C_{sat} (μg/kg)	Final indoor exposure soil conc., (μg/kg)
8.67E+01	1.56E+03	8.67E+01	2.28E+05	8.67E+01

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

SL-ADV
Version 3.0, 02/03

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)   YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)   YES [X]

Soil Vapor Emissions To Indoor Air
Commercial/Industrial Exposure Scenario

Chemical: Tetrachloroethylene

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Chemical Initial soil conc., C_R (µg/kg)
127184	

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_T (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)
20	15	15	215

ENTER — Totals must add up to value of L_T (cell G28)

Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)
15		

ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability): S
OR
ENTER User-defined stratum A soil vapor permeability, k_v (cm²):

ENTER Stratum A SCS soil type	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)
S	1.5	0.43	0.15	0.006

ENTER Stratum B SCS soil type	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)

ENTER Stratum C SCS soil type	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	244	0.1	2

ENTER Average vapor flow rate into bldg., Q_{soil} (L/m): [ ]
OR
Leave blank to calculate: 5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{nc} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	0.2

Used to calculate risk-based soil concentration

MORE

END

	Diffusivity in air, D_a (cm²/s)	Diffusivity in water, D_w (cm²/s)	Henry's law constant at reference temperature, H (atm-m³/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm³/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)	Physical state at soil temperature, (S,L,G)
	7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	6.0E-06	3.5E-02	L

END

Parameter	Symbol (units)	Value
Exposure duration,	τ (sec)	7.88E+08
Source-building separation,	L_T (cm)	1
Stratum A soil air-filled porosity,	θ_a^A (cm³/cm³)	0.280
Stratum B soil air-filled porosity,	θ_a^B (cm³/cm³)	ERROR
Stratum C soil air-filled porosity,	θ_a^C (cm³/cm³)	ERROR
Stratum A soil total fluid saturation,	S_{te} (cm³/cm³)	0.257
Stratum A soil intrinsic permeability,	k_i (cm²)	1.01E-07
Stratum A soil relative air permeability,	k_{rg} (cm²)	0.703
Stratum A soil effective air permeability,	k_v (cm²)	7.10E-08
Floor-wall seam perimeter,	X_{crack} (cm)	3,844
Initial soil concentration used,	C_R (µg/kg)	1.00E+00
Bldg. ventilation rate,	$Q_{building}$ (cm³/s)	1.25E+05
Area of enclosed space below grade,	A_B (cm²)	9.24E+05
Crack-to-total area ratio,	η (unitless)	4.16E-04
Crack depth below grade,	Z_{crack} (cm)	15
Enthalpy of vaporization at ave. soil temperature,	$\Delta H_{v,TS}$ (cal/mol)	9,451
Henry's law constant at ave. soil temperature,	H_{TS} (atm-m³/mol)	1.40E-02
Henry's law constant at ave. soil temperature,	H'_{TS} (unitless)	5.83E-01
Vapor viscosity at ave. soil temperature,	μ_{TS} (g/cm-s)	1.78E-04
Stratum A effective diffusion coefficient,	D^{eff}_A (cm²/s)	5.62E-03
Stratum B effective diffusion coefficient,	D^{eff}_B (cm²/s)	0.00E+00
Stratum C effective diffusion coefficient,	D^{eff}_C (cm²/s)	0.00E+00
Total overall effective diffusion coefficient,	D^{eff}_T (cm²/s)	5.62E-03
Diffusion path length,	L_d (cm)	1
Convection path length,	L_p (cm)	15
Soil-water partition coefficient,	K_d (cm³/g)	9.30E-01
Source vapor conc.,	C_{source} (µg/m³)	5.12E+02
Crack radius,	r_{crack} (cm)	0.10
Average vapor flow rate into bldg.,	Q_{soil} (cm³/s)	8.33E+01
Crack effective diffusion coefficient,	D^{crack} (cm²/s)	5.62E-03
Area of crack,	A_{crack} (cm²)	3.84E+02
Exponent of equivalent foundation Peclet number,	$\exp(Pe')$ (unitless)	2.88E+251
Infinite source indoor attenuation coefficient,	α (unitless)	NA
Infinite source bldg. conc.,	$C_{building}$ (µg/m³)	NA
Infinite source β term	(unitless)	6.32E+01
Finite source ψ term	(sec)⁻¹	1.92E-03
Finite source time for source depletion,	τ_D (sec)	1.70E+07
Exposure duration > time for source depletion	(YES/NO)	YES
Finite source indoor attenuation coefficient,	$\langle\alpha\rangle$ (unitless)	NA
Mass limit source bldg. conc.,	$C_{building}$ (µg/m³)	2.81E-03
Final finite source bldg. conc.,	$C_{building}$ (µg/m³)	NA
	$C_{building}$ (µg/m³)	2.81E-03
Unit risk factor,	URF (µg/m³)⁻¹	6.0E-06
Reference conc.,	RfC (mg/m³)	3.5E-02

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
2.43E+02	3.64E+03	2.43E+02	2.28E+05	2.43E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

SOIL VOC EMISSIONS TO INDOOR AIR
RESIDENTIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS
SOIL GAS:INDOOR AIR ATTENUATION FACTOR = 0.001

Soil Gas Concentration Data

ENTER	ENTER		ENTER		ENTER
Chemical	Soil gas conc., C_g ($\mu g/m^3$)	OR	Soil gas conc., C_g (ppmv)		Chemical
CAS No. (numbers only, no dashes)					
127184	3.88E+02				Tetrachloroethylene

Enter soil gas concentration in only one set of units.

MORE ←

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Depth below grade to bottom of enclosed space floor, L_F (cm)	Soil gas sampling depth below grade, L_s (cm)	Average soil temperature, T_s (°C)	Totals must add up to value of Ls (cell C24)	Soil stratum A SCS soil type (used to estimate soil vapor permeability)	User-defined stratum A soil vapor permeability, k_v (cm^2)
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, h_B (cm)	Thickness of soil stratum C, h_C (cm) (Enter value or 0)
15	15	10	15		
				(Enter value or 0)	
				S	OR

MORE ←

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	Stratum A soil total porosity, n^A (unitless)	Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	Stratum B soil total porosity, n^B (unitless)	Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)
1.5	0.43	0.15			

(continued stratum C columns)

ENTER	ENTER	ENTER
Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	Stratum C soil total porosity, n^C (unitless)	Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)

MORE ←

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Enclosed space floor thickness, L_{crack} (cm)	Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	Enclosed space floor length, L_B (cm)	Enclosed space floor width, W_B (cm)	Enclosed space height, H_B (cm)	Floor-wall seam crack width, w (cm)
15	40	961	961	244	0.1

ENTER
Indoor air exchange rate, ER (1/h)
1

ENTER	ENTER	ENTER	ENTER	ENTER
Averaging time for carcinogens, AT_c (yrs)	Averaging time for noncarcinogens, AT_{nc} (yrs)	Exposure duration, ED (yrs)	Exposure frequency, EF (days/yr)	
70	30	30	350	
15				

END

Diffusivity in air, Da (cm2/s)	Diffusivity in water, Dw (cm2/s)	Henry's law constant at reference temperature, H (atm-m3/mol)	Henry's law constant reference temperature, TR (oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, TB (oK)	Critical temperature, TC (oK)	Molecular weight, MW (g/mol)	Unit risk factor, URF (mg/m3)-1	Reference conc., RfC (mg/m3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	165.83	5.9E-06	6.0E-01

END

Parameter	Value
Exposure duration, t (sec)	9.46E+08
Source-building separation, L_T (cm)	1
Stratum A air-filled porosity, θ_{aA} (cm3/cm3)	0.28
Stratum B soil air-filled porosity, θ_{aB} (cm3/cm3)	ERROR
Stratum C air-filled porosity, θ_{aC} (cm3/cm3)	ERROR
Stratum A effective total fluid saturation, S_{te} (cm3/cm3)	0.25729443
Stratum A soil intrinsic permeability, k_i (cm2)	9.92425E-08
Stratum A soil relative air permeability, k_{rg} (cm2)	0.703228129
Stratum A effective vapor permeability, k_v (cm2)	6.97901E-08
Floor-wall seam perimeter, X_{crack} (cm)	3844
Soil gas conc. (mg/m3)	388.1
Bldg. ventilation rate, $Q_{building}$ (cm3/s)	62594.20111

Parameter	Value
Area of enclosed space below grade, A_B (cm2)	923521
Crack-to-total area ratio, h (unitless)	0.000416233
Crack depth below grade, Z_{crack} (cm)	15
Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	9552.934617
Henry's law constant at ave. soil temperature, H_{TS} (atm-m3/mol)	7.83E-03
Henry's law constant at ave. soil temperature, H_{TS} (unitless)	0.337067044
Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	0.000175414
Stratum A effective diffusion coefficient, D_{effA} (cm2/s)	5.62E-03
Stratum B effective diffusion coefficient, D_{effB} (cm2/s)	0
Stratum C effective diffusion coefficient, D_{effC} (cm2/s)	0
Total overall effective diffusion coefficient, D_{effT} (cm2/s)	0.00561629
Diffusion path length, L_d (cm)	1

Parameter	Value
Convection path length, L_p (cm)	15
Source vapor conc., C_{source} (mg/m3)	388.1
Crack radius, r_{crack} (cm)	0.1
Average vapor flow rate into bldg., Q_{soil} (cm3/s)	67.38925148
Crack effective diffusion coefficient, D_{crack} (cm2/s)	0.00561629
Area of crack, A_{crack} (cm2)	384.4
Exponent of equivalent foundation Peclet number, $\exp(Pe_f)$ (unitless)	2.211E+203
Infinite source indoor attenuation coefficient, a (unitless)	0.001062797
Infinite source indoor bldg. conc., $C_{building}$ (ug/m3)	0.41247487
Unit risk factor, URF (mg/m3)-1	0.0000059
Reference conc., RfC (mg/m3)	0.6

END

Q_{soil} (L/min)
4.0

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.0E-06	6.6E-04

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

SCROLL
DOWN
TO "END"

END

SOIL VOC EMISSIONS TO INDOOR AIR
COMMERCIAL/INDUSTRIAL EXPOSURE SCENARIO
HIGH-PERMEABILITY (SANDY) SOILS
SOIL GAS:INDOOR AIR ATTENUATION FACTOR = 0.0005

Soil Gas Concentration Data

ENTER		ENTER		ENTER
Chemical CAS No. (numbers only, no dashes)		Soil gas conc., C_g ($\mu g/m^3$)	OR	Soil gas conc., C_g (ppmv)
127184		1.30E+03		

Enter soil gas concentration in only one set of units.

Chemical
Tetrachloroethylene

ENTER	ENTER	ENTER
Depth below grade to bottom of enclosed space floor, L_F (cm)	Soil gas sampling depth below grade, L_s (cm)	Average soil temperature, T_s (°C)
15	15	10

Totals must add up to value of Ls (cell C24)

ENTER	ENTER	ENTER	ENTER	ENTER
Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, h_B (Enter value or 0) (cm)	Thickness of soil stratum C, h_C (Enter value or 0) (cm)	Soil stratum A SCS soil type (used to estimate soil vapor permeability)	User-defined stratum A soil vapor permeability, k_v (cm^2)
15	15		S	OR

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	Stratum A soil total porosity, n^A (unitless)	Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	Stratum B soil total porosity, n^B (unitless)	Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	Stratum C soil total porosity, n^C (unitless)	Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
1.5	0.43	0.15						

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Enclosed space floor thickness, L_{crack} (cm)	Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	Enclosed space floor length, L_B (cm)	Enclosed space floor width, W_B (cm)	Enclosed space height, H_B (cm)	Floor-wall seam crack width, w (cm)	Indoor air exchange rate, ER (1/h)
15	40	961	961	244	0.1	2

ENTER	ENTER	ENTER	ENTER
Averaging time for carcinogens, AT_c (yrs)	Averaging time for noncarcinogens, AT_{nc} (yrs)	Exposure duration, ED (yrs)	Exposure frequency, EF (days/yr)
70	25	25	250

MORE ←

END

Diffusivity in air, Da (cm2/s)	Diffusivity in water, Dw (cm2/s)	Henry's law constant at reference temperature, H (atm-m3/mol)	Henry's law constant reference temperature, TR (oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H\alpha,\beta$ (cal/mol)	Normal boiling point, TB (oK)	Critical temperature, TC (oK)	Molecular weight, MW (g/mol)	Unit risk factor, URF (mg/m3)-1	Reference conc., RfC (mg/m3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	165.83	5.9E-06	6.0E-01

END

Parameter	Symbol	Units	Value
Exposure duration	t	(sec)	7.88E+08
Source-building separation	L_T	(cm)	1
Convection path length	L_p	(cm)	15
Area of enclosed space below grade	A_B	(cm2)	923521
Crack-to-total area ratio	h	(unitless)	0.000416233
Crack depth below grade	Z_{crack}	(cm)	15
Stratum A air-filled porosity	q_{aA}	(cm3/cm3)	0.28
Stratum B soil air-filled porosity	q_{aB}	(cm3/cm3)	ERROR
Stratum C air-filled porosity	q_{aC}	(cm3/cm3)	ERROR
Source vapor conc.	C_{source}	(mg/m3)	1304
Crack radius	r_{crack}	(cm)	0.1
Stratum A effective total fluid saturation	S_{te}	(cm3/cm3)	0.25729443
Enthalpy of vaporization at ave. soil temperature	$\Delta H_{v,TS}$	(cal/mol)	9552.934617
Henry's law constant at ave. soil temperature	H_{TS}	(atm-m3/mol)	7.83E-03
Henry's law constant at ave. soil temperature	H_{TS}	(unitless)	0.337067044
Source effective diffusion coefficient	D_{source}	(cm2/s)	67.38925148
Average vapor flow rate into bldg.	Q_{soil}	(cm3/s)	0.005616299
Stratum A soil intrinsic permeability	k_i	(cm2)	9.92425E-08
Vapor viscosity at ave. soil temperature	μ_{TS}	(g/cm-s)	0.000175414
Stratum A effective diffusion coefficient	D_{effA}	(cm2/s)	5.62E-03
Stratum B effective diffusion coefficient	D_{effB}	(cm2/s)	0
Stratum C effective diffusion coefficient	D_{effC}	(cm2/s)	0
Crack effective diffusion coefficient	D_{crack}	(cm2/s)	0.005616299
Area of crack	A_{crack}	(cm2)	384.4
Stratum A soil relative air permeability	k_{rg}	(cm2)	0.703228129
Stratum A soil effective vapor permeability	k_v	(cm2)	6.97901E-08
Total overall effective diffusion coefficient	D_{effT}	(cm2/s)	0.005616299
Exponent of equivalent foundation Peclet number	$\exp(Pe^f)$	(unitless)	2.211E+203
Infinite source indoor attenuation coefficient	a	(unitless)	0.000531398
Floor-wall seam perimeter	X_{crack}	(cm)	3844
Diffusion path length	L_d	(cm)	1
Infinite source bldg. conc.	$C_{building}$	(mg/m3)	0.692943596
Bldg. ventilation rate	$Q_{building}$	(cm3/s)	125188.4022
Unit risk factor	URF	(mg/m3)-1	0.0000059
Reference conc.	RfC	(mg/m3)	0.6

END

Qsoil (L/min)
4.0

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.0E-06	7.9E-04

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

SCROLL
DOWN
TO "END"

END

APPENDIX 5

DEVELOPMENT OF SOIL LEACHING SCREENING LEVELS

The method used by the Ontario Ministry of Environment and Energy (MOEE 1996) to develop soil screening levels for leaching concerns was adopted from guidance published by the Massachusetts Department of Environment Protection (MADEP). This appendix provides relevant sections and appendices from the 1994 MADEP publication entitled "Background Documentation for the Development of the Massachusetts Contingency Plan Numerical Standards".

BACKGROUND DOCUMENTATION

FOR THE DEVELOPMENT OF THE

MCP NUMERICAL STANDARDS

Massachusetts Department of Environmental Protection
Bureau of Waste Site Cleanup
and
Office of Research and Standards

April 1994

MCP APPENDIX F

DEVELOPMENT OF

**DILUTION/ATTENUATION FACTORS
(DAFs)**

FOR THE LEACHING-BASED

SOIL STANDARDS

DEVELOPMENT OF DILUTION/ATTENUATION FACTORS (DAFs) FOR THE LEACHING-BASED SOIL STANDARDS

INTRODUCTION

The Massachusetts Department of Environmental Protection has developed dilution attenuation factors (DAFs) in order to establish soil cleanup criteria for the protection of groundwater from leaching of residual contaminants in soil. DEP has adopted the modeling approach utilized by the State of Oregon in a similar process. This report describes the model and its application toward the development of DAFs for Massachusetts for a limited number of compounds of concern, and the subsequent development of one regression algorithm that relates DAFs developed by Oregon to those applicable in Massachusetts, and another algorithm that relates DAFs to chemical specific parameters. The pathway to groundwater is only one consideration in the final determination of an acceptable soil cleanup level.

THE OREGON MODEL

The Oregon model (Anderson, 1992) assumes a generic setting for a release of contaminant in the unsaturated zone and then applies the combination of SESOIL and AT123D models to estimate impact of the initial soil loading on a receptor assumed directly downgradient of the site via the groundwater pathway. The SESOIL and AT123D models, while previously individually developed (see References, Bonazountas, 1984 and Yeh, 1981), are a part of the risk assessment Graphical Exposure Modeling System (GEMS) developed by USEPA. A pc-based version of this (PCGEMS) was developed for USEPA by General Sciences Corporation (1989). The two models can now be linked so that SESOIL can pass leachate loadings to the saturated zone AT123D model.

The Oregon model's site setting (see Figure 1) assumes a 3-meter thick unsaturated zone, divided into three 1-meter layers. Contamination is initially released in the middle layer, as might occur for a leaking tank or for a residual contaminant remaining after some remedial excavation with clean cover backfill, and is uniformly distributed in this layer over a 10 meter by 10 meter area. The unsaturated zone and aquifer are assumed to be the same sandy soil with uniform properties. The upper and lower unsaturated zone layers are initially clean, as is the aquifer.

FIGURE 1
CONCEPTUAL SETTING
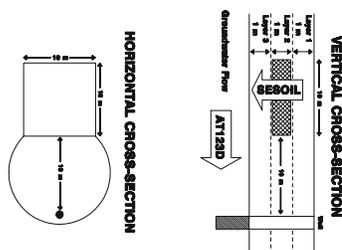
Source: Anderson (1991)

SESOIL inputs include the soil type parameters, chemical properties, application rates, and the climatic conditions of the area. The model is run as a transient monthly estimator of leachate volumes and concentrations. Initially, no other transport mechanisms other than leaching, partitioning, and volatilization were considered. Oregon used default values in SESOIL for Portland Oregon climatic conditions, but distributed total precipitation uniformly over the year.

SESOIL was initially found to overestimate losses via volatilization. A parameter, the volatilization fraction (VOLF), was introduced to allow adjustment of losses through this pathway and allow a site-specific calibration. This factor may be varied in time and space. The Oregon study used a uniform VOLF factor of 0.2, based on consultation with a panel of experts. One other soil-related parameter is the disconnectedness index. This parameter varies for and within soil types. Two values are given as SESOIL defaults, and the larger, 7.5, has been used in the simulations. An increase in this parameter appears to result in a higher soil moisture, lower leachate rates, and somewhat lower DAFs (i.e., is more conservative) for the compounds run.

AT123D inputs include general aquifer properties, source configuration, loadings to groundwater, soil partition coefficients, and dispersivity values. The aquifer is assumed to be infinitely wide and thick. The pc-based version of AT123D accepts monthly transient loading rates calculated by SESOIL, and also provides a preprocessor for input file preparation and editing. In utilizing the model, the center of the 10 by 10 meter source area is assumed to be at coordinates 0,0,0. The positive x-axis is in the direction of flow. Calculated concentrations are maximum along the x-axis (y=0) and at the water table surface (z=0). Since the receptor is assumed to be 10 meters from the downgradient edge of the source area, the concentration at x=15, y=0, and z=0 represents the receptor location. Oregon used longitudinal, transverse, and vertical dispersivities of 20m, 2m, and 2m, respectively. These values seem high for a sandy aquifer, but the values have been retained to be consistent with the Oregon base values and to be protective of the Commonwealth's sensitive aquifers on Cape Cod. DAFs are proportional to the dispersivities, particularly sensitive to the vertical dispersivity.

Oregon ran the model for 10 indicator compounds and then developed a multiple linear regression model relating the DAF to the organic partition coefficient (K_{oc}) and the Henry's Law constant (H) to provide preliminary DAFs for sixty other organic compounds. Soil cleanup levels were generated based on the regression algorithm and a safe drinking water level for each compound. In some cases, risk based levels determined by other pathways were lower than the levels required to protect groundwater. In these instances, the lower value was selected as the soil target level. A similar approach was taken to develop the MCP Method 1 Standards, as described in Section 5.3.

SIMULATIONS FOR MASSACHUSETTS

The approach taken to develop DAFs for Massachusetts was to determine the effect that varying the location (changing the climatic conditions from Portland, Oregon to Boston, Massachusetts in SESOIL) would have on the Oregon calculated DAFs. If the model system was essentially linear with respect to loading, then DAFs already calculated for Oregon would be directly related to DAFs appropriate for Massachusetts, and the general algorithm developed by Oregon (with coefficients adjusted) could also be used to estimated DAFs for other compounds. To this end, model runs were made using the Oregon input values for SESOIL and AT123D with the exception of climate parameter values. Eight indicator compounds were selected: benzene, toluene, ethylbenzene, o-xylene, trichloroethene, tetrachloroethene, 1,1,1-trichloroethane, and naphthalene.

The input values for SESOIL are shown in Tables F-1 through F-4, and those for AT123D are shown on Table F-5. Depending on the mobility of the compound through the transport pathway, model runs varied from 2 years to 6 years as necessary to determine the maximum concentration attained at the receptor location for a specific compound. A point to consider in the adoption of the Oregon values, or adjustments to them, is the need to agree with the physio-chemical parameters that were used to generate the DAFs. Even in the eight indicator compounds selected, various accepted databases provide some widely varying values for S, H and K_{oc}. For example, for PCE, H is reported with an order of magnitude difference, and values of K_{oc} and solubility differing by a factor of 2 are reported for ethylbenzene in the literature.

Output concentrations at the selected receptor location demonstrated a cyclical nature due to seasonal variations in precipitation and net recharge. Maximum concentrations were not always attained in the first cycle due to seasonal variability. However, the model output appeared to be linear with respect to the initial loading, allowing soil cleanup levels to be estimated based on the linear DAF approach. Table F-6 shows the model-based DAFs for Oregon and Massachusetts, and also, based on listed safe drinking water levels and the estimated DAFs for Massachusetts, what soil target levels would be for the eight indicator compounds run.

Default climate values for Boston as contained in the
SESOIL model. Latitude = 42 degrees.

TABLE F-2
SOIL PARAMETER VALUES
FOR THE SESOIL MODEL

Intrinsic permeability $=1\text{x}10^{-7}$ cm^2
Source area$=$1,000,000 cm^2
Porosity $=0.3$
Disconnectedness index $= 7.5$
Soil bulk density $= 1.5$ gm/cm^3
Soil organic carbon $= 0.1\%$

Layer 1 thickness $= 100$ cm
Layer 2 thickness $= 100$ cm
Layer 3 thickness $= 100$ cm
No further sublayering specified

Clay content $= 0\%$

All other parameters set to zero
except those to indicate uniform
parameters in all layers.

TABLE F-3
APPLICATIONS DATA
FOR SESOIL MODEL

Application month = October only
layer = 2
rate = 1500 microgm/cm^2
year = 1 only

Based on the area, thickness and bulk density, this produces an initial concentration of 10 ppm. No other sources are added.

Volatile fraction (VOLF) = 0.2

Uniform in time and space.

All other parameter values set to zero.

TABLE F-4
CHEMICAL DATA FOR SESOIL MODEL

Compound	MW	K_{oc} ml/g	S mg/L	H atm-m^3/mol	DA cm^2/sec
benzene	78	83	1780	0.0055	0.109
ethylbenzene	106	575	161	0.00343	0.093
toluene	92	270	535	0.00668	0.100
o-xylene	106	302	171	0.00527	0.093
TCE	131	124	1100	0.00912	0.083
PCE	166	468	200	0.00204	0.075
1,1,1-TCA	133	157	730	0.0231	0.080
naphthalene	128	1288	31	0.00118	0.085

MW = molecular weight
K_{oc} = organic carbon partition coefficient
S = solubility in water
H = Henry's Law constant
DA = diffusion coefficient in air

TABLE F-5
AT123D MODEL INPUT PARAMETER VALUES

Soil bulk density = 1.5 g/cc
Porosity = 0.3
Hydraulic conductivity = 0.5 m/hr
Hydraulic gradient = 0.005
Longitudinal dispersivity = 20.0 m
Transverse dispersivity = 2.0 m
Vertical dispersivity = 2.0 m

Loading (kg/hr) passed by SESOIL link program
Distribution coefficient = K_{oc} * fraction organic carbon
Source area = 10 m by 10 m, centered at 0,0
initial z penetration = 0

Degradation rates initially zero

TABLE F-6
MODEL OUTPUT DRAFT DAFS
COMPARISON AND SOIL LEVELS

Oregon Compound	Mass DAF	DAF	DRINKING WATER LEVEL mg/L	SOIL TARGET LEVEL ppm
benzene	44.4	56.5	0.005	0.28
ethylbenzene	103.5	121.1	0.700	84.8
toluene	64.5	80.6	1.000	80.6
o-xylene	65.4	83.3	10.000	833.3
TCE	65.4	76.3	0.005	0.38
PCE	73.0	86.2	0.005	0.43
1,1,1-TCA	133.2	169.2	0.200	33.8
naphthalene	207.0	222.2	0.280	62.2

STATISTICAL RELATIONSHIPS

A linear regression was run on the eight DAF data pairs with DAFs for Oregon as the independent variable. The model was :

$$DAF_{Mass} = A + B*DAF_{Oregon}$$

That is, the regression was not forced through the origin. For the eight data pairs, the equation was

$$DAF_{Mass} = 12.39 + 1.053*DAF_{Oregon}$$

with an r of 0.9913. Thus, over the range of data spanned by these eight compounds, the correlation appears good. Table F-7 shows a comparison of the DAFs calculated by the model and those by the linear regression equation above for the eight indicator compounds. Differences between the two methods are less than 10 percent.

A multiple linear regression algorithm for DAF(Mass) as a function of K_{oc} and H was also developed along the same lines as that developed by Oregon. This allows the calculation of DAFs for compounds for which Oregon did not consider, and which also may be used exclusively from the linear regression cited above. Two models were considered:

    (a) $DAF = A + B*H + C*K_{oc}$, and
    (b) $DAF =$ $B*H + C*K_{oc}$.

where A, B, and C are regression coefficients. As with the Oregon analysis, it proved that the constant term was not statistically different from zero, and the simpler second model was adopted. Regression analysis yielded:

The fit here is somewhat better than the r-squared value of .956 for the Oregon model in that one compound with a large residual (carbon tetrachloride with a residual of 30) was not used here, and the average difference is much smaller with the eight

$$DAF = 6207 * H + 0.166 * K_{oc}$$

compounds than for Oregon's ten. Table F-8 shows the relationship between the model DAFs and the regression expression predicted values. Only one compound varies more than 10 percent while six of the eight have percent differences less than five.

TABLE F-7
COMPARISON BETWEEN MODEL DAFS
AND LINEAR REGRESSION DAFS
BASED ON OREGON DAFS

Compound	Model DAF	Regr. DAF	%Diff.
benzene	56.5	59.1	4.60
ethylbenzene	121.1	121.4	0.25
toluene	80.6	80.3	-0.37
o-xylene	83.3	81.3	-2.40
TCE	76.3	81.3	6.55
PCE	86.2	89.3	3.60
1,1,1-TCA	169.2	152.6	-9.81
naphthalene	222.2	230.4	3.69

TABLE F-8
RESULTS OF THE MULTIPLE LINEAR REGRESSION
EQUATION FOR H AND KOC

Compound	Model DAF	Predicted	% Diff.
benzene	56.5	47.9	-15.2
ethylbenzene	121.1	116.7	- 3.6
toluene	80.6	86.3	7.1
o-xylene	83.3	82.8	- 0.5
TCE	76.3	77.2	1.2
PCE	86.2	90.4	4.9
1,1,1-TCA	169.2	169.4	0.1
naphthalene	222.2	221.1	- 0.5

BIODEGRADATION

It is intuitive that biodegradation may play an important role in attenuating the potential impact of residual contaminants in soils on groundwater. However, there are a great many site-specific conditions that will determine actual biodegradation rates. Further, literature values cover a wide range and the exact conditions under which they were estimated are rarely known. Literature values should be applied only with great caution

to any estimation of contaminant fate and transport. In order to evaluate the potential effect of biodegradation, rate constants cited by Howard et al (1991) were input to the model for the five compounds of the eight indicator compounds known to degrade aerobically. This eliminated the chlorinated compounds TCE, PCE, and 1,1,1-TCA. In addition, one additional rate for benzene (0.002/day from the California LUFT guidance) was also run. Four runs were made for benzene as the most critical compound, at the California rate, at the high and low rates cited by Howard and at the geometric mean of the Howard high and low rates. Only one rate, the low Howard value, was used for each of the other four compounds. The reason for this will be seen shortly.

The degradation rates in Howard appear to be high, with half lives for the BTEX compounds on the order of days. This implies that within a year, residual concentrations in soil would be reduced by biodegradation several (three to six) orders of magnitude. Table F-9 presents the results of the model runs.

For all situations except for the two lowest rates for benzene, the DAFs become huge. In essence, this indicates that only trace amounts of the contaminants ever reach the groundwater table. Soil target level estimation using large DAFs and the linear approach should be done only with extreme caution. A contaminant in the subsurface will attempt to reach equilibrium concentrations in the air, moisture and sorbed to soil. At some total concentration, equilibrium solubility in moisture would be exceeded, indicating the probable presence of free product. In this case, the linearity and basic assumptions in the model may be violated. Of further consideration are the potential toxic effects on the biological population as concentrations of the compounds increase. For these circumstances, estimation of soil target levels considering biodegradation is very difficult.

TABLE F-9
RESULTS OF THE BIODEGRADATION RUNS

Compound	Rate in Soil 1/day	Rate in Water 1/day	DAF
benzene	0.002	0.001 *	84.7
benzene	0.0433	0.000963	2178.
benzene	0.0775	0.00817	1.5×10^4
benzene	0.1386	0.0693	5.7×10^7
toluene	0.0315	0.02475	8.7×10^6
ethylbenzene	0.0693	0.00304	1.8×10^{13}
o-xylene	0.02475	0.001899	2.8×10^5
naphthalene	0.01444	0.00269	8.6×10^{10}

* Note: Odencrantz's article on the California LUFT parameter values did not cite a rate for water. This was assumed here to be half that in soil. Note that not much more degradation occurs in the aquifer due to the rapid travel time to the receptor of about 11 to 12 days (large longitudinal dispersivity and low retardation).

SENSITIVITY

A detailed sensitivity analysis was not done at this point in time. However, Oregon did perform some sensitivity analyses, and sensitivity of these models as applied in California's LUFT program is discussed in another article (Odencrantz, et al, 1992)

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APPENDIX 6

RATIONAL FOR MOEE ECOTOXICITY-BASED SOIL CRITERIA

RATIONALE FOR
THE DEVELOPMENT AND APPLICATION
OF GENERIC SOIL, GROUNDWATER AND SEDIMENT
CRITERIA FOR USE AT
CONTAMINATED SITES IN ONTARIO

Report prepared by:

Standards Development Branch
Ontario Ministry of Environment and Energy

December 1996

Report prepared for:

Ontario Ministry of Environment and Energy

Version 1.1

Version 1.1

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Version 1.1

1 INTRODUCTION

This document describes the rationale behind the development of effects-based generic soil, groundwater and sediment quality criteria, to be used in place of the 1989 soil clean-up levels in the remediation of contaminated sites in Ontario. This rationale document replaces the document entitled "Soil Clean-up Guidelines for Decommissioning of Industrial Lands: Background and Rationale for Development". The use and application of these criteria are described in the "Guideline for Use at Contaminated Sites in Ontario" (1996) which replaces the MOE 1989 "Guideline for the Decommissioning and Clean-up of Sites in Ontario" and the 1993 "Interim Guidelines for the Assessment and Management of Petroleum Contaminated Sites in Ontario".

This introduction is the first of four sections comprising the rationale document. Section 2 provides an overview of the environmental approach, guiding principles, and remediation options and their linkage with the criteria development process. Section 3 describes in detail, the process and assumptions used in the development of the soil and groundwater criteria. This includes a full description of the Massachusetts methodology that was adopted for use in Ontario, as well as the modifications and additional components that were utilized. All references utilized in this document are listed in Section 4. The criteria tables, on which decisions relating to site remediation will be based, are found in Appendix A. Also provided in Appendix A are summary tables of all criteria components. Additional scientific documents and supporting information for the development of the criteria are found in Appendix B.

2 OVERVIEW OF THE APPROACH, GUIDING PRINCIPLES AND MAJOR ASPECTS OF THE CRITERIA DEVELOPMENT PROCESS.

2.1 General Approach

The revision of the Ministry's 1989 guideline for the decommissioning and clean-up of contaminated sites is predicated on providing a more flexible, environmentally protective approach which will be applicable to a greater number of environmental contaminants and provide an increased level of guidance and remediation options to proponents. From an environmental aspect, this flexibility was achieved by more closely matching receptors and exposure pathways to land and groundwater use categories, and to the extent possible, to site conditions which affect contaminant transport and exposure.

The MOEE has participated in the development of a protocol for setting effects-based soil quality criteria under the National Contaminated Sites Remediation Program of the Canadian Council of Ministers of Environment (CCME). These protocols are summarized in the CCME document entitled "A Protocol for the Derivation of Ecological Effects Based and Human Health Based Soil Quality Criteria for Contaminated Sites." (1994). However, as the development of soil clean-up criteria based on CCME criteria documents will take several years, the MOEE

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explored other options to provide effects-based criteria.

The Department of Environmental Protection, Bureau of Waste Site Cleanup and the Office of Research and Standards for the Commonwealth of Massachusetts, have jointly produced chemical-specific standards for use under their revised Massachusetts Contingency Plan (MCP) which was promulgated in October 1993. Generic criteria for 106 inorganic/organic contaminants were developed using a risk characterization approach to provide protection to human and environmental health.

After a review of the general assumptions and multi-media components of the MCP approach, a decision was made to adopt and modify this approach for generic soil and groundwater "risk-based" site remediation criteria in Ontario. The MCP approach was selected as it appeared to best meet Ontario's needs for a large number of effects-based soil and groundwater criteria which address most potential human health and aquatic exposure pathways. It was also chosen because both the toxicological assessments and exposure scenarios carried out by the Massachusetts Department of Environmental Protection (DEP) had been subjected to extensive public consultation and had been promulgated as standards.

All assumptions for risk characterization, dose-response and toxicity information, methods, calculations and data inputs to the MCP standards development process are detailed in the Massachusetts document entitled "Background Documentation for the Development of the MCP Numerical Standards" (1994). The relevant portions of this document have been included in Appendix B.5. Modifications were made to various inputs into the MCP spreadsheets so that the criteria for the 106 chemicals would better represent the Ontario situation.

3.2.3 Additional Soil Criteria Components Incorporated by MOEE

3.2.3.1 Terrestrial Ecological Soil Criteria Component

The MCP approach addresses primarily human-health effects with some consideration of indirect ecological effects (aquatic) through the soil/groundwater leaching-based concentrations (GW-3). However, there is no consideration for direct soil contact exposure for terrestrial ecological receptors. As MOEE is also committed to providing ecological protection, ecotoxicity criteria were included in the development process for soil criteria. Ontario ecological effects-based criteria for inorganics were incorporated into the process to develop surface restoration criteria for soils. The decision was made that terrestrial ecological protection for direct contact below the 1.5 meter depth, was not appropriate. Therefore, only human health and indirect ecological effects through leaching (via groundwater to surface water) were considered for sub-surface soil criteria (>1.5m depth).

The Netherlands have also developed ecosystem toxicity-based soil criteria for several inorganic and organic contaminants. These concentrations were utilized in the process when Ontario ecological criteria did not already exist. The Massachusetts DEP developed soil and groundwater criteria (based on human health) for 106 inorganic and organic chemicals. The integration of additional criteria for metals and inorganic parameters, based on ecological data, increased the soil chemical list to 115.

The following inorganic parameters were added to the soil criteria development process: barium, boron, chromium (total), cobalt, copper, molybdenum, electrical conductivity (mS/cm), nitrogen (total), and sodium absorption ratio (SAR).

The Massachusetts DEP chose to develop a human health risk-based criterion for chromium III and VI but not for total chromium. MOEE has ecological effects-based criteria for total chromium. Therefore, the committee decided to include total chromium on the chemical list. The Phytotoxicology Section of the MOEE Standards Development Branch has recently developed soil quality criteria for boron based on phytotoxicity effects data. Boron has been included in the chemical list; however, the boron criteria, which address the 'available' boron in soil are based on a 'hot water extract' rather than bulk soil analysis. The development of the boron criteria is described in detail in Appendix B.3.

3.2.3.1.1 Exposure Pathways and Protection of Ecological Receptors at Various Land Uses

In determining numerical criteria for soil based on potential ecological effects, it was necessary to make judgements as to what receptors should be protected and what level of protection was required for each land use category. A full range of philosophies exist, from protection against the earliest detectable effects to any species that could potentially occur on a site, or be affected by contamination at a site, to protection against the most severe of effects to very common

species which normally occur on sites of a particular land use category. The philosophy that is adopted can, therefore, strongly influence the final generic criteria derived. This section outlines the level of ecological protection which forms the basis for the development of the ecological criteria for each of the three land use categories: agricultural, residential/parkland and industrial/commercial.

To the extent permitted by available scientific evidence, these types of protection were incorporated into the criteria development process for each land use category. However, it must be stressed that in many cases, the lack of scientific evidence prohibited the development of an ecological component.

Agricultural Land Use Category

Soils that are to be used for agricultural purposes should be able to support the growth of a wide range of commercial crops as well as the raising of livestock. Contamination due to anthropogenic activities should not result in noticeable yield reductions of commercial crops that cannot be remedied through normal farming practices. Soil concentrations of chemical parameters also should be sufficiently low that there are no known or suspected adverse impacts on domestic grazing animals, including migratory and transitory wildlife, through both direct soil ingestion or through ingestion of plants grown on the soil. Since soil invertebrates and microorganisms provide important functions for the overall health of a soil, and the plants supported by the soil, these populations should not be adversely affected to the point where functions such as nutrient cycling, soil:root symbiotic relationships and decomposition are significantly reduced or impaired.

A consideration of all of the above factors also must recognize that in certain situations, agricultural chemicals are utilized because they are capable of selective toxicological action against undesirable plants and soil organisms. In these situations, a case specific approach will be necessary in the soil remediation process.

Residential/Parkland Land Use Category

The need for protection of commercial crops in the residential/parkland land use category is not as apparent as for agriculture; nevertheless, the common practice of growing backyard vegetable gardens and allotment gardens results in there being little practical difference between the plant species to be protected at residential sites and those at agricultural sites. Since parkland is included with residential land use in this category, it is also necessary to protect migratory and transitory species that may utilize such sites. The major difference from agricultural sites is that, for residential/parkland sites, the protection of domestic grazing animals such as sheep and cattle is not an important consideration.

Industrial/Commercial Land Use Category

It is not necessary to require as high a degree of protection for on-site ecological receptors at an industrial or commercial site as it is for agricultural or residential/parkland sites. The soil at industrial sites should be capable of supporting the growth of some native and ornamental trees, shrubs and grasses, but, it is not as important to protect against yield or growth reductions to the same extent as for residential and agricultural properties, nor to protect as wide a range of species. Since it would be highly undesirable to have transitory or migratory species being affected by utilizing any specific industrial or commercial property, criteria should be sufficiently protective to prevent such adverse effects on these species.

3.2.3.1.2 Existing MOEE Soil Clean-up/Decommissioning Guidelines (SCUGs)

The rationale on which the 1989 guidelines was based was described in the MOE publication "Soil Clean-up Guidelines for Decommissioning of Industrial Lands: Background and Rationale for Development" (MOE, 1991). This publication has been replaced and relevant information applicable to those parameters that were utilized in the 1995 criteria development process can be found in Appendix B.3.

Soil clean-up criteria were developed for the following parameters: As, Cd, Cr (total), CrVI, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Zn, soil pH range, Electrical Conductivity and Sodium Absorption Ratio. However, in the case of Cd, Pb, and Hg, the 1989 criteria were influenced more by human health considerations rather than ecological effects, and accordingly these criteria were discarded (with the exception of Cd for the agricultural land use category).

Re-examination of the rationale for the 1989 ecological criteria indicated that although the process was much less rigorous than the most recent CCME protocol for the development of ecological criteria, it did offer several important features:

- the criteria have been utilized in Ontario for 15 years without any evidence to indicate that protection was not provided

- the criteria have been widely adopted for use in other jurisdictions including the CCME without any evidence of problems

- early evidence from the new CCME process which has been applied to a limited number of parameters indicates that the 1989 ecological criteria are in reasonable agreement with the results from this process

- a thorough review of the available literature combined with an experimental program by the Phytotoxicology Section has confirmed that in the case of copper, the 1989 values are

fully in line with values that emerge from this type of analysis

Based on this assessment, a decision was made to incorporate the 1989 ecological criteria. The following additional considerations were utilized.

A strong argument can be made that the 1989 SCUGs for Cd (i.e. 3 ppm for coarse-textured soils and 4 ppm for medium/fine textured soils) are still valid for the agricultural use category. Cd is an element that is not readily eliminated in mammals, and it is known to bio-accumulate in tissue. Grazing animals that are ingesting Cd accumulated in plants growing on contaminated soils and from the soils themselves may be more at risk from Cd accumulation than is accounted for by any criterion higher than the current MOEE SCUG of 3 ppm (e.g. the Netherlands ecotoxicity criterion for Cd is 12 ug/g). It is known that wild ungulates grazing on lands with natural background Cd concentrations can accumulate Cd in the kidneys to the point where the kidneys are unfit for consumption. Some species of food plants (i.e. spinach and lettuce) have been observed to accumulate Cd in the edible portions of the plant to levels that would be of concern, even at relatively low soil Cd concentrations. Although the change of the Cd guideline from 3 μg/g to 12 ug may be suitable for residential purposes, there is little evidence that it takes the above factors into consideration for agricultural land uses.

The CCME draft document "A Protocol for the Derivation of Ecological Effects Based and Human-Health Based Soil Quality Criteria" (1994) contains some equations that are useful for estimating guidelines based on food ingestion and soil ingestion by animals utilizing the land. Using these equations and data presented in the draft CCME assessment document on Cadmium (Canadian Soil Quality Criteria for Contaminated Sites: Cadmium), a guideline of 3 μg Cd/g is indicated to be appropriate for agricultural use. These equations are presented below. For these reasons, it was decided to continue using the 3 μg/g guideline for cadmium for agricultural use unless and until there is substantial justification to indicate that it too should be changed. The following is a CCME calculation of soil quality criteria based on food ingestion by animals (e.g. cattle):

EDFI = DTED x BW/FIR
= 0.0028 mg Cd kg-1BW x day-1 x 100kg / 3kg day-1
= 0.093 mg/kg dw food

SQCfi = EDFI x AFfi/BCF
= 0.093 mg/kg x 0.85/0.025
= 3.16 mg/kg

CCME calculation of soil quality criteria based on soil ingestion by animals

EDFI = DTED x BW/SIR
$\quad\quad$ = 0.0028 mg Cd kg-1BW x day-1 x 100kg / 0.54kg day-1
$\quad\quad$ = 0.519 mg/kg dw soil

SQCsi = EDSI x AFsi/ BF
$\quad\quad$ = 0.519 mg/kg x 0.18/ 0.025
$\quad\quad$ = 3.74 mg/kg

Where:

SQCfi =	Soil Quality Criteria for Food Ingestion
SQCsi =	Soil Quality Criteria for Soil Ingestion
EDFI =	Estimated dose for Food Ingestion
DTED =	Daily Threshold Effects Dose
BW =	Body Weight
FIR =	Food Ingestion Rate
SIR =	Soil Ingestion Rate
AFfi =	Apportionment factor for Food ingestion
AFsi =	Apportionment Factor for Soil Ingestion
BCF =	Bioconcentration Factor
BF =	Bioavailability Factor

The 1989 Cu, Mo, and Se SCUG criteria for agricultural/residential/parkland land uses were developed to protect grazing livestock. The industrial/commercial SCUG criteria for these three parameters provided protection to vegetation only. For this reason, the industrial/commercial SCUG criteria (for coarse-textured and medium-fine textured soils) were selected for both the residential/parkland and industrial/commercial land use categories where grazing animals are not likely to occur. The Cu, Mo and Se SCUG values that were based on protection of grazing livestock will apply to the agricultural land use category only.

The electrical conductivity of soil is essentially a measurement of the total concentration of soluble salts in the soil solution and can have a large osmotic influence on plant growth, as well as on soil organisms. The existing MOEE SCUGs for electrical conductivity (E.C.) of a soil required the use of a saturated extract. This procedure is time consuming and results are subjective; i.e. the end point of saturation is determined by the technician's expert opinion.

A fixed 2:1 water:soil procedure eliminates this uncertainty and provides a more rapid and reliable test. Both MOEE (Phytotoxicology Section) and Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) now use the 2:1 procedure for most routine samples. The water:soil ratio used for the extract affects the resultant electrical conductivity; hence, the existing SCUG of 2.0 mS/cm (agricultural/residential/parkland) and 4.0 mS/cm (commercial/industrial) were adjusted to account for the change in water:soil ratio for this

criterion.

Data in Extension Bulletin E-1736 (Michigan State University, 1983) made available to the committee by the Department of Land Resource Science, University of Guelph, show that for a given E.C., in saturation extract, the expected E.C. in a 2:1 water:soil ratio would be one third of the former. The appropriate E.C. for both agricultural and residential/parkland land use categories is 0.667 mS/cm. When rounded to 0.7 mS/cm, this value corresponds with the boundary between what McKeague (1978) states "may result in a slightly stunted condition in most plants" and "slight to severe burning of most plants". This is a reasonable concentration at which to establish the E.C. SCUG and confirmed the use of the divisor of 3 as a conversion factor. Using this conversion factor, the industrial/commercial SCUG for E.C. becomes 1.4 mS/cm.

Provisional soil clean-up guidelines were also produced in 1989 for Sb, Ba, Be and V for which the knowledge of their potential adverse phytotoxic effects was more limited than for the other inorganic parameters. These provisional criteria were also incorporated into the current modified criteria development process.

In all cases, MOE SCUG criteria values for coarse-textured soils, as well as medium and fine textured soils have been adopted from the 1989 guidelines for use in the current criteria development process. Coarse-textured soils are defined here as greater than 70% sand. The medium and fine textured soil SCUGs are 20-25% higher than the corresponding values for coarse-textured soils.

3.2.3.1.3 The Netherlands "C Level" Ecotoxicity Criteria

The Dutch government published soil and groundwater clean up guidelines, "ABC values", in 1983. These guidelines have undergone revision over the last 7 years to include both human health and ecological effects-based data. A new set of C-values has been proposed (Vegter, 1993). The final integrated C-value includes a human health component, as well as the ecological component, and includes risk management adjustments. The ecological component of the C-value is derived by taking the geometric mean or the average value of the logarithm of the No Observable Adverse Effect Concentration (NOEC) (Denneman and van Gestel, 1990). This means that the C-value represents the chemical concentration at which the NOEC for 50% of the ecological species has been exceeded.

For the purposes of this guideline, the ecotoxicity component of the C-value was incorporated into the soil criteria development process in all cases where a 1989 MOE SCUG value was not available. In addition to the references listed above, more information on the Dutch guidelines can be found in the following references: van den Berg and Roels (1993); van den Berg et al. (1993); and Denneman and Robberse (1990).

Version 1.1

Appendix B.3: Rationale for MOEE Ecotoxicity-Based Soil Criteria.

(IN: *Rational For The Development And Application Of Generic Soil Groundwater, And Sediment Criteria For Use At Contaminated Sites In Ontario,* Standards Development Branch, Ontario Ministry of Environment and Energy, December 1996 (ISNB: 0-7778-2818-9)

Version 1.1

Appendix B.3

This appendix replaces the rationale which was the basis for the 1989 ecotoxicity-based soil remediation criteria. The original rationale is described in the 1991 MOE publication entitled "Soil Clean-up Guidelines for Decommissioning of Industrial Lands: Background and Rationale for Development". Those parameters in the original rationale, which were based on human health effects, have been removed. A rationale for a boron soil criterion (hot water extract), based on protection of vegetation and grazing animals, has been added.

All relevant information applicable to MOEE ecotoxicity-based soil values utilized in the 1995 soil remediation criteria development process are contained in the following sections. As more information on these and other soil parameters becomes available, the information will be included in this appendix as part of the rationale for deriving ecotoxicity criteria for soil remediation.

<p style="text-align: center;">APPENDIX B.3 TABLE OF CONTENTS</p>

1 BACKGROUND

In February, 1984, the Phytotoxicology Section was requested by the Halton-Peel District Office of the MOE to provide input into the development of soil criteria for the decommissioning of certain oil refinery lands. Proposed land uses made it desirable to have separate criteria for residential and industrial redevelopment. Monenco Consultants, on behalf of one of the oil companies, undertook a large-scale literature survey in an attempt to relate contaminant concentrations in soil to toxic effects on vegetation and animals. As a result of this effort, Monenco recommended site-specific ecotoxicity-based soil criteria for a number of contaminants (Monenco Ontario Ltd., 1984a & 1984b).

Subsequent to the above-described exercise, the Phytotoxicology Section was asked to recommend soil clean-up criteria for additional contaminants. Provisional criteria for these additional elements were developed, based on literature reviews. The Phytotoxicology Section was requested by the MOE Waste Management Branch to develop clean-up levels for agricultural land use. This request was brought to the attention of the Sludge and Waste Utilization Committee. It was the opinion of this Committee that the residential/parkland clean-up levels previously developed were, with minor modifications/qualifications, also suitable for application to agricultural situations.

2 RATIONALES FOR ECOTOXCITY-BASED SOIL CRITERIA

The recommended ecotoxicity-based soil remediation criteria are shown in Section 5.1 (Table 5.1). The rationales for their development include considerations of phytotoxicity and animal health. In general, the most conservative of these considerations was used to established agricultural and residential soil criteria. Redevelopment as parkland also was felt to warrant this conservative approach, because parkland often is used by children at play, and occasionally is used for allotment gardening.

Different industrial/commercial remediation levels (normally set at twice the residential levels) were recommended where the residential and industrial criteria were both set on the same basis but where phytotoxic concerns were judged to be considerably less significant in the industrial/commercial environment. For two elements (molybdenum and selenium), residential soil remediation levels were established to prevent toxicity to grazing animals, whereas a higher industrial level was established to prevent toxicity to vegetation.

Provisional ecotoxicity-based soil remediation criteria recommended for four additional contaminants are shown in Section 5.2 (Table 5.2). Because knowledge of potential adverse effects of these elements in soil is generally more limited than for the Table 1 criteria, the provisional criteria were purposefully established in an even more conservative vein.

Since the mobility and availability of metals in soils may be highly dependent on form of

the metal, soil texture, pH and organic matter content, site-specific considerations of these parameters may reveal the suitability of different criteria. For example, where metals are known to be present in specific forms of very limited availability, higher levels may be considered. Furthermore, in researching the clean-up criteria, Monenco Consultants utilized data from studies on medium to fine textured soils (i.e. sandy soils excluded), in which mobility (availability) of metals would be lower than in coarse-textured sand (hence, metals are less likely to accumulate in sand than in clay). Therefore, it is recommended that the remediation levels for the metals and metalloids be reduced in the case of coarse-textured (greater than 70% sand) mineral soils (less than 17% organic matter). This recommendation is reflected in the remediation levels shown in Tables 5.1 and 5.2.

The rationales for individual parameters are summarized in the following sections (RATIONAL FOR As, B, Cr, co, Cu, Mo, Ni, Ag, Zin, SAR, Sb, Ba, Be, V; NOT INCLUDED IN THIS APPENDIX).

APPENDIX 7

SUMMARY OF MADEP CARBON RANGE AND
TOTAL PETROLEUM HYDROCARBON RISK-BASED
SCREENING LEVELS

SUMMARY OF MADEP CARBON RANGE AND TOTAL PETROLEUM HYDROCARBON TOXICITY AND PHYSIO-CHEMICAL SURROGATES

CARBON RANGE	Human Toxicity Surrogate	Aquatic Life Protection Surrogate	Organic Carbon Coefficient (Koc) (cm^3/g)	Henry's Law Constant (H) $(atm\text{-}m^3/mol)$
Aliphatics				
C5 to C8	n-hexane	n-hexane	2.27E+03	1.29E+00
C9 to C12	10 x n-hexane	decane	1.50E+05	1.56E+00
C9 to C18	10 x n-hexane	decane	6.80E+05	1.66E+00
C19 to C36	100 x n-hexane	cyclododecane	-	-
Aromatics				
C9 to C10	xylenes	ethylbenzene	1.78E+03	7.92E-03
C11 to C22	naphthalene /pyrene	PAHs	5.00E+03	7.20E-04
**Total Petroleum Hydrocarbon (TPH)	naphthalene/ pyrene	PAHs	5.00E+03	7.20E-04

* MADEP referred to both naphthalene & pyrene for the C11 to C22 range RfD in their original documents. Both have an Oral RfD of 0.03 mg/kg-d and inhalation RFC of 0.071 mg/m^3 (0.02 mg/kg-d) in MADEP guidance.

**TPH conservatively assumed to be 100% C11 to C22 aromatic compounds (major component of diesel#2, #3-#6 fuel oil, JP-4).

Reference:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs)
(mg/kg)

*RESIDENTIAL SURFACE SOIL (S-1) - Drinking Water Resource Threatened (GW-1)

Carbon Range		Final S-1/GW-1 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	**C5 to C8**	100	730	3400	**100**	5000
	C9 to C12	1000	15000	140000	**1000**	20000
	C9 to C18	1000	15000	490000	**1000**	20000
	C19 to C36	2500	230000	-	**2500**	20000
Aromatics	**C9 to C10**	100	810	**69**	100	5000
	C11 to C22	200	810	**170**	1000	10000
TPH-general	**-**	200	800	**200**	1000	10000

*See Massachusetts DEP MCP for full description S-1, S-2 and S-3 soils.

RESIDENTIAL SURFACE SOIL (S-1) - Groundwater Discharge to Surface Water (GW-3)

Carbon Range		Final S-1/GW-3 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	**C5 to C8**	100	730	34000	**100**	5000
	C9 to C12	1000	15000	690000	**1000**	20000
	C9 to C18	1000	15000	2500000	**1000**	20000
	C19 to C36	2500	230000	-	**2500**	20000
Aromatics	**C9 to C10**	100	810	1400	**100**	5000
	C11 to C22	800	**810**	25000	1000	10000
TPH-general	**-**	800	**800**	25000	1000	10000

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs)
(mg/kg)

*OCCUPATIONAL SURFACE SOIL (S-2) - Drinking Water Resource Threatened (GW-1)

Carbon Range		Final S-1/GW-1 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	500	1500	3400	**500**	5000
	C9 to C12	2500	36000	140000	**2500**	20000
	C9 to C18	2500	36000	490000	**2500**	20000
	C19 to C36	5000	670000	-	**5000**	20000
Aromatics	C9 to C10	100	2000	**69**	500	5000
	C11 to C22	200	2000	**170**	2500	10000
TPH-general	-	200	2000	**200**	2500	10000

*See Massachusetts DEP MCP for full description S-1, S-2 and S-3 soils.

OCCUPATIONAL SURFACE SOIL (S-2) - Groundwater Discharge to Surface Water (GW-3)

Carbon Range		Final S-1/GW-3 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	500	1500	34000	**500**	5000
	C9 to C12	2500	36000	690000	**2500**	20000
	C9 to C18	2500	36000	2500000	**2500**	20000
	C19 to C36	5000	670000	-	**5000**	20000
Aromatics	C9 to C10	500	2000	1400	**500**	5000
	C11 to C22	2000	**2000**	25000	2500	10000
TPH-general	-	2000	**2000**	25000	2500	10000

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs)
(mg/kg)

*ISOLATED SUBSURFACE SOIL (S-3) - Drinking Water Resource Threatened (GW-1)

Carbon Range		Final S-1/GW-1 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	500	7100	3400	**500**	5000
	C9 to C12	5000	170000	140000	**5000**	20000
	C9 to C18	5000	170000	490000	**5000**	20000
	C19 to C36	5000	3100000	-	**5000**	20000
Aromatics	C9 to C10	100	9300	**69**	500	5000
	C11 to C22	200	9300	**170**	5000	10000
TPH-general	-	200	9300	**200**	5000	10000

*See Massachusetts DEP MCP for full description S-1, S-2 and S-3 soils.

ISOLATED SUBSURFACE SOIL (S-3) - Groundwater Discharge to Surface Water (GW-3)

Carbon Range		Final S-1/GW-3 RBSL	Direct Exposure	Leaching	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	500	7100	34000	**500**	5000
	C9 to C12	5000	170000	690000	**5000**	20000
	C9 to C18	5000	170000	2500000	**5000**	20000
	C19 to C36	5000	3100000	-	**5000**	20000
Aromatics	C9 to C10	500	9300	1400	**500**	5000
	C11 to C22	5000	9300	25000	**5000**	10000
TPH-general	-	5000	9300	25000	**5000**	10000

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

Summary of Massachusetts DEP Carbon Range/TPH Risk-Based Screening Levels (RBSLs)
(ug/L)

*GROUNDWATER - Drinking Water (GW-1)

Carbon Range		Final GW-1 RBSL	Human Consumption	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	400	**420**	5000	100000
	C9 to C12	4000	**4200**	5000	100000
	C9 to C18	4000	**4200**	5000	100000
	C19 to C36	5000	42000	**5000**	100000
Aromatics	C9 to C10	200	**230**	5000	100000
	C11 to C22	200	**230**	5000	100000
TPH-general	-	200	**230**	5000	100000

*See Massachusetts DEP MCP for full description GW-1, GW-2 and GW-3 groundwater.

*GROUNDWATER - Discharge to Surface Water (GW-3)

Carbon Range		Final GW-3 RBSL	*Aquatic Life Protection	Nuisance Ceiling	Upper Concentration Level
Aliphatics	C5 to C8	4000	**3900**	50000	100000
	C9 to C12	20000	**18000**	50000	100000
	C9 to C18	20000	**18000**	50000	100000
	C19 to C36	20000	**21000**	50000	100000
Aromatics	C9 to C10	4000	**4300**	50000	100000
	C11 to C22	30000	**30000**	50000	100000
TPH-general	-	20000	**20000**	50000	100000

* Aquatic Life Protection = aquatic life criteria x assumed ten-fold diuition factor.

References:

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Public Hearing Draft: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, January 17, 1997.

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Redline/Strikeout Version: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, October 31, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1997, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, November 7, 1997, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

MADEP, 1999, Revisions to the Massachusetts Contingency Plan, 310 CMR 40.000 - Spreadsheet Detailing VPH/EPH Standards Derivation: Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, May 25, 1999, www.magnet.state.ma.us/dep/bwsc/vph_eph.html

APPENDIX 8

SUMMARY OF FEBRUARY 2005 UPDATES TO JULY 2003 ESL DOCUMENT

Screening For Environmental Concerns At Sites
With Contaminated Soil and Groundwater (February 2005)

Summary of Significant Updates to July 2003 Edition

Chemicals with greater than +/-25% change in final ESLs (highlighted in red in Volume 1 summary tables and Appendix 1):

Chemical	Basis of Update
Acetone	Adjusted to updated [1]USEPA RfDs
Aldrin	Adjusted to reflect [3]OEHHA ABS values
Cadmium	Adjusted to reflect [2]Basin Plan AWQC
Chloroform	Adjusted to reflect [3]OEHHA ABS values and updated [1]USEPA RfDs
Chloromethane	Adjusted to updated [1]USEPA CSFs
Cobalt	Adjusted to updated [1]USEPA RfDs
Cyanide	Henry's constant corrected
Dichlorobenzene, 1,3	Adjusted to updated [1]USEPA RfDs
Ethanol	New chemical
Ethylbenzene	Adjusted to retracted [1]USEPA CSFs
Lead	Updated residential [3]OEHHA CHHSL
Mercury	Adjusted to reflect [3]OEHHA RfDs
Naphthalene	Adjusted to reflect [3]OEHHA CSFs
Perchlorate	Adjusted to reflect [3]OEHHA PHG
Toluene	Adjusted to reflect [3]OEHHA RfDs
TPH-middle distillates	Ceiling levels adjusted to reflect recalculated odor index
Trichlorobenzene, 1,2,4	Adjusted to reflect [3]OEHHA ABS values and updated [1]USEPA RfDs
Trichloroethane, 1,1,1	Corrected RfC
Xylenes	Adjusted to reflect [3]OEHHA RfDs (human health); [4]chronic surface water goal updated.

1. Adjusted to reflect updated toxicity used in UEPA Region IX Preliminary Remediation Goals (USEPA 2004). Refer to Table J in Appendix 1.
2. Adjusted to reflect changes in *Water Quality Control Plan* (Basin Plan, RWQCBSF 1995)
3. Adjusted to reflect reference doses or skin absorption factors used in OEHHA California Human Health Screening Levels (CalEPA 2004b, revised January 2005) or revised Public Health Goal. Lead soil screening level for residential sites updated to 150 mg/kg. Refer to Tables J and K in Appendix 1.
4, Chronic surface water goal for xylenes updated. Refer to Tables F-4a and F-4c in Appendix 1.

Date: 12/30/04
Section: Volume 1, Tables A-D; Volume 2, Tables A-D series, E series, F-1a, F-1b, F-6, J, K series
Update: Human health-related toxicity factors updated with respect to toxicity factors presented in OEHHA CHHSLs document (CalEPA, 2004b) and USEPA Region XI PRGs (USEPA 2004). Reference doses incorporated in CHHSLs used in place of USEPA reference doses when available. Skin absorption factors used in CHHSLs also referred to of defaults used in USEPA PRGs. The majority of changes to human health ESLs were

relatively minor except as noted above. Inhalation reference dose for TPH also incorporated into health-based ESLs. Target hazard quotient used for TPH ESLs adjusted to 0.5. The corrected Henry's constant for cyanide led to significant reductions in the leaching based soil screening levels for that chemical.

Date: 12/14/04
Section: Volume 1, Tables A-D; Volume 2, Tables A-D series, E series, F-1a, F-1b, F-6, J, K series
Update: Risk-based ESLs for ethylbenzene updated to reflect removal of NCEA cancer slope factor from October 2004 USEPA Region IX PRG document. Groundwater ESLs presented in Volume 1 were not affected.

Date: 8/9/04
Section: Volume 1, Tables A-D; Volume 2, Tables A-D series, E series, F-1a, F-1b, F-6, J, K series
Update: Risk-based ESLs for naphthalene updated with respect to toxicity factors for carcinogenic effects adopted by OEHHA on August 2, 2004. Groundwater ESLs presented in Volume 1 were not affected.

Date: 2/5/04
Section: Volume 1, Table F
Update: Surface water screening levels for estuarine habitats corrected to reflect screening levels in Table F-2c of Appendix 1. Original table mistakenly referenced screening levels for marine habitats. Note that screening levels for drinking water concerns are not considered under this scenario.

Date: 9/4/03
Section: Volume 1, Tables A, B, C and D; Volume 2, Tables A, B, C, D series and Table G.
Update: Leaching based soil screening levels for perchlorate added to Table G and affected tables updated.

Date: 9/2/03
Section: Volume 1, Table E; Volume 2, Tables E-2 and E-3.
Update: Inhalation toxicity factors for carbon tetrachloride, 1,2 dibromo-3-dichloropropane and 1,1,22 Tetrachloroethane corrected. Indoor air screening levels (Table E-3) and correlative soil gas screening levels (Table E-2) were corrected. Soil and groundwater screening levels for vapor emission concerns were not affected.

Date: 8/4/03
Section: Volume 1, Tables A, B, C and D; Volume 2, Tables A, B, C, D series and Table G.
Update: Leaching based soil screening levels for bis(2-ethylhexl)phthalate and pentachlorophenol corrected in Appendix 1, Table G. Corrections also made to affected tables of Volume 1 and Appendix 1 of Volume 2 as noted below. Note that final ESLs in Volume 1 were not affected in all cases.

APPENDIX 9

COMPARISON OF OEHHA CHHSLS AND USEPA REGION IX PRGS TO CORRELATIVE ESLS

Table 1. Comparison of Soil Screening Levels for Nonvolatile Chemicals Based on Direct Exposure to Contaminated Soil: Residential Land Use (Inhalation, Ingestion and Dermal Absorption)

Chemical	[1]OEHHA CHHSL mg/kg	basis[4]	[2]RWQCB Region 2 ESLs mg/kg	[5]	[3]U. S. EPA Region 9 PRG mg/kg	[5]
Organic Acidic Chemicals						
2,4-D	6.9E+02	(nc)	-		6.9E+02	
2,4,5-T	5.5E+02	(nc)	-		6.1E+02	(d)
Pentachlorophenol	4.4E+00	(ca)	4.4E+00		3.0E+00	(a)
Organic Neutral Chemicals						
Aldrin	3.3E-02	(ca)	3.2E-02		2.9E-02	(d)
Benzo(a)pyrene	3.8E-02	(ca)	3.8E-02		6.2E-02	(a)
Chlordane	4.3E-01	(ca)	4.4E-01		1.6E+00	(a)
DDD	2.3E+00	(ca)	2.3E+00		2.4E+00	(d)
DDE	1.6E+00	(ca)	1.6E+00		1.7E+00	(d)
DDT	1.6E+00	(ca)	1.6E+00		1.7E+00	(d)
Dieldrin	3.5E-02	(ca)	3.4E-02		3.0E-02	(d)
1,4 Dioxane	1.8E+01	(ca)	1.8E+01		4.4E+01	(a)
Dioxin (2,3,7,8-TCDD)	4.6E-06	(ca)	4.6E-06		3.9E-06	(a)
Endrin	2.1E+01	(nc)	4.1E+00	(c)	1.8E+01	(d)
Heptachlor	1.3E-01	(ca)	1.3E-01		1.1E-01	(a)
Lindane	5.0E-01	(ca)	5.0E-02		4.4E-01	(a)
Kepone	3.5E-02	(ca)			6.1E-02	(a)
Methoxychlor	3.4E+02	(nc)	6.9E+01	(c)	3.1E+02	(d)
Mirex	3.1E-02	(ca)			2.7E-01	(a)
PCBs	8.9E-02	(ca)	2.2E-01		2.2E-01	(a)
Toxaphene	4.6E-01	(ca)	4.6E-01		4.4E-01	(a)
Inorganic Chemicals						
Antimony and compounds	3.0E+01	(nc)	6.1E+00	(c)	3.1E+01	(d)
Arsenic	7.0E-02	(ca)	6.0E-02		3.9E-01	(a)
Barium and compounds	5.2E+03	(nc)	1.0E+03	(c)	5.4E+03	(d)
Beryllium and compounds	1.5E+02	(nc)	2.9E+01	(c)	1.5E+02	(d)
Beryllium oxide	9.1E-02	(ca)	-		-	(d)
Beryllium sulfate	2.1E-04	(ca)	-		-	(d)
Cadmium and compounds	1.7E+00	(ca)	1.7E+00		3.7E+01	(a)
Chromium III	1.0E+05	(max)	2.3E+04	(c)	1.0E+05	
Chromium VI	1.7E+01	(ca)	1.8E+00	(e)	3.0E+01	(a)
Cobalt	6.6E+02	(nc)	1.0E+01	(e)	9.0E+02	(d)
Copper and compounds	3.0E+03	(nc)	6.1E+02	(c)	3.1E+03	(d)
Fluoride	4.6E+03	(nc)	-		3.7E+03	(d)
Lead and lead compounds	1.5E+02	(nc)	1.5E+02	*	4.0E+02	(h)
Lead acetate	2.3E+00	(ca)	-		-	
Mercury and compounds	1.8E+01	(nc)	3.7E+00	(c)	2.3E+01	(d)
Molybdenum	3.8E+02	(nc)	7.6E+01	(c)	3.9E+02	(d)

Chemical	[1]OEHHA CHHSL		[2]RWQCB Region 2 ESLs		[3]U. S. EPA Region 9 PRG	
	mg/kg	basis[4]	mg/kg	[5]	mg/kg	[5]
Nickel and compounds	1.6E+03	(nc)	3.1E+02	(c)	1.6E+03	
Nickel subsulfide	3.8E-01	(ca)	-		-	
Perchlorate	postponed		1.5E+00	(c)	7.8E+00	ca/nc
Selenium	3.8E+02	(nc)	7.6E+01	(c)	3.9E+02	(d)
Silver and compounds	3.8E+02	(nc)	7.6E+01	(c)	3.9E+02	(d)
Thallium and compounds	5.0E+00	(nc)	1.0E+00	(c)	5.2E+00	(d)
Vanadium and compounds	5.3E+02	(nc)	1.1E+02	(c)	5.5E+02	(d)
Zinc	2.3E+04	(nc)	4.6E+03	(c)	2.3E+04	

1. California Human Health Screening Levels (CHHSLs) published by OEHHA (CalEPA 2004b).

2 Environmental Screening Levels (ESLs) published by SFBRWQCB Region 2 (February 2005), Appendix 1, Table K-1.

3 Preliminary Remediation Goals (PRGs) published by U.S. EPA Region 9 (USEAP 2004).

4 (ca) denotes that the screening number is based on a carcinogenic potency factor, (nc) denotes that the screening number is based on a RfD for chronic toxic effects other than cancer, (nc)* DTSC leadspread was used to compute the values for lead, (max) values greater than 10^5 were set at 10^5.

5 Explanation for difference with the CHHSL: (a) California toxicity criterion differs from the corresponding U.S. EPA criterion, (b) denotes that a new California toxicity criterion for the chemical is expected to be published during 2005, (c) denotes that the ESL was calculated by setting the hazard quotient equal to 0.2, whereas the CHHSLs and PRGs were calculated using a hazard quotient of 1, (d) denotes that, in calculating the PRG, it was assumed that dermal absorption of the chemical is 0%, (e) based on a trench worker exposure.

Table 2. Comparison of Indoor Air and Soil Gas Levels for Vapor Intrusion Concerns: Residential Land Use

Chemical	[1]OEHHA CHHSL Concentration in Indoor Air (µg/m³)	Concentration in Soil Gas (µg/m³)	basis[4]	[2]RWQCB Region 2 ESLs Concentration in Indoor Air (µg/m³)	Concentration in Soil Gas (µg/m³)	[5]	[3]U. S. EPA Region 9 PRG for Ambient Air Concentration in Indoor Air (µg/m³)	[5]
Benzene	8.40 E-02	3.62 E+01	(ca)	8.5E-02	8.5E+01		2.5E-01	(a)
Carbon tetrachloride	5.79 E-02	2.51 E+01	(ca)	5.7E-02	5.7E+01		1.3E-01	(a)
1,2-Dichloroethane	1.16 E-01	4.96 E+01	(ca)	1.2E-01	1.2E+02		1.1E+03	
cis-1,2 Dichloroethylene	3.65 E+01	1.59 E+04	(nc)	7.3E+00	7.3E+03	(c)	3.7E+01	
Trans-1,2-Dichloroethylene	7.30 E+01	3.19 E+04	(nc)	1.5E+01	1.5E+04	(c)	7.3E+01	(a)
Ethylbenzene	postponed	postponed	(b)-	4.2E+02	4.2E+05	(c)	1.7E+00	(a)
Mercury, elemental	9.40 E-02	4.45 E+01	(nc)				3.1E-01	
Methyl tert butyl ether	9.35 E+00	4.00 E+03	(ca)	9.4E+00	9.4E+03		3.7E+00	
Naphthalene	7.20 E-02	3.19 E+01	(ca)	7.1E-02	7.1E+01		3.1E+00	(a)
Tetrachloroethylene	4.12 E-01	1.80 E+02	(ca)	4.1E-01	4.1E+02		3.2E-01	
Tetraethyl lead	3.65 E-04	2.06 E-01	(nc)					
Toluene	3.13 E+02	1.35 E+05	(nc)	6.3E+01	6.3E+04	(c)	4.0E+02	
[6]TPH (gasolines)	not included	not included		2.6E+01	2.6E+04	(c)	not included	
[6]TPH (middle distillates)	not included	not included		1.0E+01	1.0E+04	(c)	not included	
1,1,1-Trichloroethane	2.29 E+03	9.91 E+05	(nc)	4.6E+02	4.6E+05	(c)	2.3E+03	(a)
Trichloroethylene	1.22 E+00	5.28 E+02	(ca)	1.2E+00	1.2E+03		1.7E-02	(a)
Vinyl Chloride	3.11 E-02	1.33 E+01	(ca)	3.2E-02	3.2E+01		1.1E-01	
m-Xylene	7.30 E+02	3.19 E+05	(nc)	1.5E+02	1.5E+05	(c)	1.1E+02.	
o-Xylene	7.30 E+02	3.15 E+05	(nc)	-	-			
p-Xylene	7.30 E+02	3.17 E+05	(nc)	-	-			

Notes:

1. California Human Health Screening Levels (CHHSLs) published by OEHHA; Table 7 "Without Engineered Fill Below Sub-slab Gravel" (CalEPA 2004b).

2 Environmental Screening Levels (ESLs) published by SFBRWQCB Region 2 (February 2005), Appendix 1, Tables E-2 (soil gas) and E-3 (Indoor Air).

3 Preliminary Remediation Goals (PRGs) published by U.S. EPA Region 9 (USEAP 2004).

4 (ca) denotes that the screening number is based on a carcinogenic potency factor, (nc) denotes that the screening number is based on a RfD for chronic toxic effects other than cancer,

5 Explanation for difference with the CHHSLs (a) California toxicity criterion differs from the corresponding U.S. EPA criterion, (c) denotes that the ESL was calculated by setting the hazard quotient equal to 0.2, whereas the CHHSLs and PRGs were calculated using a hazard quotient of 1; ESL model also assumes soil gas-to-indoor air attenuation factor of 1/1000 for residential sites whereas the CHHSLs were calculated using an attenuation factor of approximately 1/500.

6 Total Petroleum Hydrocarbons (TPH) as gasolines and middle distillates (diesel, jet fuel, etc.) not included in OEHHA document but required for use of ESLs.

Table 3. Comparison Soil Screening Levels for Nonvolatile Chemicals Based on Direct Exposure to Contaminated Soil: Commercial/Industrial Land Use (Inhalation, Ingestion and Dermal Absorption)

Chemical	[1]OEHHA CHHSL mg/kg	basis[4]	[2]RWQCB Region 2 ESLs mg/kg	[5]	[3]U. S. EPA Region 9 PRG mg/kg	[5]
Organic Acidic Chemicals						
2,4-D	7.7E+03	(nc)			7.7E+03	
2,4,5-T	6.1E+03	(nc)			6.2E+03	(d)
Pentachlorophenol	1.3E+01	(ca)	1.3E+01		9.0E+00	(a)
Organic Neutral Chemicals						
Aldrin	1.3E-01	(ca)	1.3E-01		1.0E-01	(d)
Benzo(a)pyrene	1.3E-01	(ca)	1.3E-01		2.1E-01	(a)
Chlordane	1.7E+00	(ca)	1.7E+00		6.5E+00	(a)
DDD	9.0E+00	(ca)	9.0E+01		1.0E+01	(d)
DDE	6.3E+00	(ca)	6.3E+00		7.0E+00	(d)
DDT	6.3E+00	(ca)	6.3E+00		7.0E+00	(d)
Dieldrin	1.3E-01	(ca)	1.3E-01		1.1E-01	(d)
1,4 Dioxane	6.4E+01	(ca)	6.4E+01		1.6E+02	
Dioxin (2,3,7,8-TCDD)	1.9E-05	(ca)	1.9E-05		1.6E-05	(a)
Endrin	2.3E+02	(nc)	4.6E+01	(c)	1.8E+02	(d)
Heptachlor	5.2E-01	(ca)	5.2E-01		3.8E-01	(a)
Lindane	2.0E+00	(ca)	2.0E+00		1.7E+00	(a)
Kepone	1.3E-01	(ca)			2.2E-01	(a)
Methoxychlor	3.8E+03	(nc)	7.7E+02	(c)	3.1E+03	(d)
Mirex	1.2E-01	(ca)			9.6E-01	(a)
PCBs	3.0E-01	(ca)	7.4E-01		7.4E-01	(a)
Toxaphene	1.8E+00	(ca)	1.8E+00		1.6E+00	(a)
Inorganic Chemicals						
Antimony and compounds	3.8E+02	(nc)	7.7E+01	(c)	4.1E+02	(d)
Arsenic	2.4E-01	(ca)	2.4E-01		1.6E+00	(a)
Barium and compounds	6.3E+04	(nc)	2.5E+03	(e)	6.7E+04	(d)
Beryllium and compounds	1.7E+03	(nc)	3.6E+01	(e)	1.9E+03	(d)
Beryllium oxide	4.1E-01	(ca)				
Beryllium sulfate	9.5E-04	(ca)				
Cadmium and compounds	7.5E+00	(ca)	7.4E+00		4.5E+02	(a)
Chromium III	1.0E+05	(max)	2.9E+05	(c)	1.0E+05	
Chromium VI	3.7E+01	(ca)	1.8E+00	(e)	6.4E+01	(a)
Cobalt	3.2E+03	(nc)	1.0E+01	(e)	1.9E+03	(d)
Copper and compounds	3.8E+04	(nc)	7.7E+03	(c)	4.1E+04	(d)
Fluoride	5.7E+04	(nc)			3.7E+04	(d)
[6]Lead and lead compounds	3.5E+03	(nc)	750	**	7.5E+02	(h)
Lead acetate	1.0E+01	(ca)				
Mercury and compounds	1.8E+02	(nc)	3.7E+01	(c)	3.1E+02	(d)

Chemical	OEHHA CHHSL[1] mg/kg	basis[4]	RWQCB[2] Region 2 ESLs mg/kg	[5]	U. S. EPA[3] Region 9 PRG mg/kg	[5]
Molybdenum	4.8E+03	(nc)	9.6E+02	(c)	5.1E+03	(d)
Nickel and compounds	1.6E+04	(nc)	1.0E+03	(e)	2.0E+04	(d)
Nickel subsulfide[6]	1.1E+04	(ca)			1.1E+04	
Perchlorate	postponed		1.9E+01	(c)	1.0E+02	
Selenium	4.8E+03	(nc)	9.6E+02	(c)	5.1E+03	(d)
Silver and compounds	4.8E+03	(nc)	9.6E+02	(c)	5.1E+03	(d)
Thallium and compounds	6.3E+01	(nc)	1.3E+01	(c)	6.7E+01	(d)
Vanadium and compounds	6.7E+03	(nc)	1.3E+03	(c)	7.2E+03	(d)
Zinc	1.0E+05	(nc)	5.8E+04	(c)	1.0E+05	

Notes:

1. California Human Health Screening Levels (CHHSLs) published by OEHHA (CalEPA 2004b).

2 Environmental Screening Levels (ESLs) published by SFBRWQCB Region 2 (February 2005), Appendix 1, Table K-2.

3 Preliminary Remediation Goals (PRGs) published by U.S. EPA Region 9 (USEAP 2004).

4 (ca) denotes that the screening number is based on a carcinogenic potency factor, (nc) denotes that the screening number is based on a RfD for chronic toxic effects other than cancer, (nc)* DTSC leadspread was used to compute the values for lead, (max) values greater than 10^5 were set at 10^5.

5 Explanation for difference with the CHHSL: (a) California toxicity criterion differs from the corresponding U.S. EPA criterion, (b) denotes that a new California toxicity criterion for the chemical is expected to be published during 2005, (c) denotes that the ESL was calculated by setting the hazard quotient equal to 0.2, whereas the CHHSLs and PRGs were calculated using a hazard quotient of 1, (d) denotes that, in calculating the PRG, it was assumed that dermal absorption of the chemical is 0%, (e) based on a trench worker exposure.

6. OEHHA CHHSLs document recommends use of lead screening level less than the CalEPA lead TTLC for hazardous waste 1,000 mg/kg based (CalEPA 2004b, Table 5).

Table 4. Comparison of Indoor Air and Soil Gas Levels for Vapor Intrusion Concerns: Commercial/Industrial Land Use

| Chemical | [1]OEHHA CHHSL | | | [2]RWQCB Region 2 ESLs | | | [3]U. S. EPA Region 9 PRG for Ambient Air | |
	Concentration in Indoor Air (µg/m³)	Concentration in Soil Gas (µg/m³)	basis[4]	Concentration in Indoor Air (µg/m³)	Concentration in Soil Gas (µg/m³)	[5]	Concentration in Indoor Air (µg/m³)	[5]
Benzene	1.41 E-01	1.22 E+02	(ca)	1.4E-01	2.4E+02		not provided	(a)
Carbon Tetrachloride	9.73 E-02	8.46 E+01	(ca)	9.5E-02	1.9E+02		“	(a)
1,2-Dichloroethane	1.95 E-01	1.67 E+02	(ca)	1.9E-01	3.9E+02		“	
cis-1,2-Dichloroethylene	5.11 E+01	4.44 E+04	(nc)	2.0E+01	2.0E+04	(c)	“	
trans-1,2-Dichloroethylene	1.02 E+02	8.87 E+04	(nc)	2.0E+01	4.1E+04	(c)	“	(a)
Ethylbenzene	postponed	postponed	(b)	5.8E+02	1.2E+06	(c)	“	(a)
Mercury, elemental	1.31 E-01	1.25 E+02	nc)	-	-		“	
Methyl tert-Butyl Ether	1.57 E+01	1.34 E+04	(ca)	1.6E+01	3.1E+04		“	
Naphthalene	1.20 E-01	1.06 E+02	(ca)	1.2E-01	2.4E+02		“	(a)
Tetrachloroethylene	6.93 E-01	6.03 E+02	(ca)	6.8E-01	1.4E+03		“	
Tetraethyl Lead	5.11 E-04	5.78 E-01	(nc)	-	-		“	
Toluene	4.38 E+02	3.78 E+05	(nc)	8.8E+01	1.8E+05	(c)		
[7]TPH (gasolines)	not included	not included		3.6E+01	7.2E+04	(c)	not included	
[7]TPH (middle distillates)	not included	not included		3.6E+01	7.2E+04	(c)	not included	
1,1,1-Trichloroethane	3.21 E+03	2.79 E+06	(nc)	6.4E+02	1.3E+06	(c)		(a)
Trichloroethylene	2.04 E+00	1.77 E+03	(ca)	2.0E+00	4.1E+03		“	(a)
Vinyl Chloride	5.24 E-02	4.48 E+01	(ca)	5.3E-02	1.1E+02		“	
m-Xylene	1.02 E+03	8.87 E+05	(nc)	2.0E+02	4.1E+05		“	
o-Xylene	1.02 E+03	8.79 E+05	(nc)			(c)	“	
p-Xylene	1.02 E+03	8.87 E+05	(nc)					

Notes:

1. California Human Health Screening Levels (CHHSLs) published by OEHHA; Table 7 "Without Engineered Fill Below Sub-slab Gravel" (CalEPA 2004b).

2 Environmental Screening Levels (ESLs) published by SFBRWQCB Region 2 (February 2005), Appendix 1, Tables E-2 (soil gas) and E-3 (Indoor Air).

3 Preliminary Remediation Goals (PRGs) published by U.S. EPA Region 9 (USEAP 2004).

4 (ca) denotes that the screening number is based on a carcinogenic potency factor, (nc) denotes that the screening number is based on a RfD for chronic toxic effects other than cancer,

5 Explanation for difference with the CHHSLs (a) California toxicity criterion differs from the corresponding U.S. EPA criterion, (c) denotes that the ESL was calculated by setting the hazard quotient equal to 0.2, whereas the CHHSLs and PRGs were calculated using a hazard quotient of 1; ESL model also assumes soil gas-to-indoor air attenuation factor of 1/2000 for residential sites whereas the CHHSLs were calculated using an attenuation factor of approximately 1/1000.

6 Total Petroleum Hydrocarbons (TPH) as gasolines and middle distillates (diesel, jet fuel, etc.) not included in OEHHA document but required for use of ESLs.